Motor Graders

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MIR PUBLISHERS MOSCOW

Э. Г. Ронинсон

АВТОГРЕЙДЕРЫ

Издательство «Высшая школа»
Москва

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Motor Graders

Translated from Russian
by V. Kochin

Mir Publishers · Moscow

First published 1985
Revised from the 1982 (second) Russian edition

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Introduction

Any construction project usually involves a great deal of earth-moving operations which are accomplished with the use of bulldozers, scrapers, graders and motor graders.

A motor grader is an earth-moving machine intended to cut a soil layer and to move it in the desired direction. It has its own power plant for propelling the driving wheels and is thus self-propelled.

The main purpose of the motor graders is to profile the roadbed, i.e. to cut soil in side ditches and move it towards the road center line for subsequent levelling. These operations are accomplished with the aid of a blade with cutting edges which is suspended from the grader frame between its front and rear axles. An important advantage of the motor grader over other types of earth-moving machines consists in that it is capable of performing virtually all earth-moving work for road and railway construction beginning with preparatory operations and ending with profiling of the roadbed.

The experience of using graders for road construction dates back to the 1870s. At those times appeared first graders that were in fact a horse-pulled waggon with a blade suspended between the front and rear wheels. The blade was slewed with respect to the waggon longitudinal axis so as to move spoil sidewards. Later the waggon was replaced with a metal frame on metal wheels and the blade was suspended from a lifting mechanism. The horses were replaced with wheeled and caterpillar tractors. The machine was controlled by a tractor driver and a grader operator. The motor grader being a combination of a grader and a tractor appeared in the 1930s. It is controlled by one operator.

A modern grader is rather a complex machine likewise

a truck or a tractor. The construction of the motor graders is being persistently improved. The main trends for improving the motor graders include:

— improving reliability and extending service life of the machines by refining production and using steels of higher grades;

— increasing engine power rating to allow the grader operation at higher speeds;

— using more sophisticated transmissions for partially automating motor grader movement control to facilitate the operator's work and increase productivity of the machine;

— implementing full-scale hydraulic control of the operating equipment (360° circle rotation, tilting and side-shifting of the blade, deflection of the blade through up to 90° for cutting slopes);

— using automatic systems for controlling the blade position in the transversal and longitudinal planes for substantially improving the accuracy of grading, diminishing the operator's fatigue and hence increasing the machine output;

— improving versatility of motor graders by widening the range of replaceable and mounted equipment;

— improving the operator's labour conditions by making the cab more comfortable by decreasing noise level and dust content, installing shock-mounted seats, increasing glazing, decreasing lever and pedal force;

— designing motor graders with articulated frames for considerably diminishing the turning radius of the machine and increasing counteraction to lateral forces acting upon the blade.

Three types of motor graders are being manufactured in the USSR: light, medium and heavy.

Light graders come in several modifications differing mainly in the gearbox construction. These differences result in some variations of performance. On request light motor graders are equipped with an automatic device for maintaining constant slope angle and elevation of the blade in grading.

Medium motor graders are equipped with transmissions of different types. Some medium graders are adapted for low-temperature operation. They are also provided with

blade automatic control systems. Light and medium motor graders use identical gearboxes which cuts production costs, simplifies in-service repair and spare supply problems.

Heavy motor graders have an all-wheel drive and a mechanical transmission. Some heavy graders come with a hydromechanical transmission.

Apart from refining production and increasing output, special measures should be taken to ensure constant readiness of the machine for use, i.e. to minimize down time periods caused by mechanical troubles. This can be achieved by well-timed and quality maintenance, proper observance of operation rules and regulations.

Motor graders should be operated by highly skilled personnel capable of ensuring reliable operation of the machine, its good working conditions and high output.

Part One

Motor Grader Construction

Chapter 1

GENERAL

1.1. Construction

Construction. A motor grader (Fig. 1.1) is a self-propelled pneumatic-tyre machine. A main frame (*7*) of the motor grader rests on a front axle (*5*) and rear tandem (*9*). An engine (*12*) and a gearbox (*10*) are attached to the frame in the vicinity of the tandem.

A blade (*8*) which is the main working member of the grader is secured to a circle mounted on a draft frame (*3*). The draft frame is attached to the main frame by its front end with the aid of a ball joint (*6*). The rear part of the draft frame is suspended by hydraulic cylinders of a blade control mechanism (*2*).

The control mechanism ensures lifting, lowering, sloping and sideshifting of the blade, its extension beyond the main frame limits to cut slopes and ditches, and a 360-deg rotation of the blade circle in the horizontal plane.

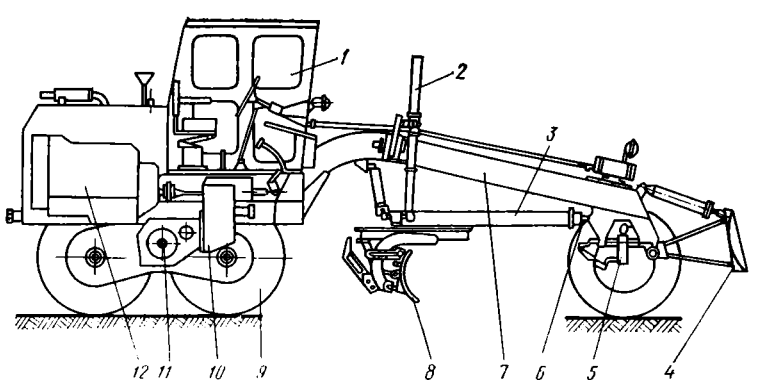


Fig. 1.1. Motor grader

1—cab; *2*—blade control mechanism; *3*—draft frame; *4*—implement; *5*—front axle; *6*—articulated joint; *7*—main frame; *8*—blade; *9*—tandem; *10*—gearbox; *11*—oscillation axle; *12*—engine

A cab (*1*) of the grader is mounted over the middle axle which allows a good observation of the blade working area. Also, locating the cab close to the gearbox and engine simplifies design of the control mechanisms.

The front part of the grader carries an auxiliary implement (*4*).

The grader front wheels are steerable and can be leaned in the vertical plane. Such an arrangement of the wheels increases the grader's stability when operating on slopes or cutting side ditches.

The tandem wheels have a fully articulated suspension and are free to swing in the longitudinal plane relative to an axle (*11*). Such a suspension precludes wheel separation from the ground surface when crossing bumps and ditches. With the grader layout shown in Fig. 1.1 the machine weight is uniformly distributed among the three axles.

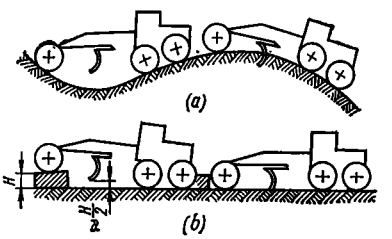


Fig. 1.2. Motor grader movement diagram

(*a*) levelling; (*b*) passing obstacles

The three-axle layout with the blade mounted within the base between the front and rear axles and the fully articulated suspension ensure a higher accuracy of grading as compared with other machines, say two-axle bulldozers and scrapers.

When crossing a bump (Fig. 1.2*a*) the blade cuts the soil. The blade is aligned with the wheels and needs not be depressed into the soil. When crossing a ditch the blade does not cut the soil but fills the ditch with the soil removed from the bump. This considerably simplifies control of the motor grader in performing grading operations. Surface irregularities cannot exert any noticeable effect upon grading quality because of the long wheel base of the machine and fully articulated suspension of the rear wheels. When one of the wheels moves up a bump, the blade which is within the machine base lifts up to a half of the bump height only (Fig. 1.2*b*).

To move the motor grader along the support surface (soil or road) a certain motive force F should be applied to it (Fig. 1.3*a*). The magnitude of this force depends on the total resistance to motion.

If the grader is travelling at a high speed, the total resistance to motion combines resistance to rolling including soil (road) friction force and actual tyre force, and air drag. In earth-moving the total resistance is made up of soil resistance to cutting, friction of soil against the steel blade and subsoil, and rolling resistance. The magnitudes of the above-mentioned resistances depend on the grader gross weight, the road surface type and conditions, the tyre type and pressure. For instance the total resistance to motion drastically rises during acceleration, when the blade encounters a hard-to-pass obstacle and on steep slopes.

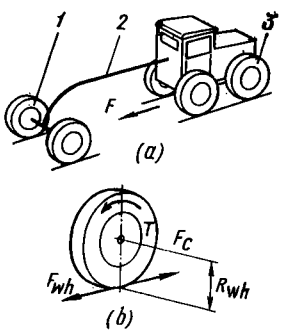


Fig. 1.3. Motor grader motive forces

(*a*) general diagram; (*b*) driving wheel force diagram; *1*, *3*—driven and driving wheels; *2*—grader frame; F—total motive force; F_{wh}—wheel motive force; F_c—wheel circumferential force; T—torque; R_{wh}—wheel rolling radius

The grader engine imparts torque to driving wheels (*3*) via the transmission so that circumferential force F_c is formed on the wheels (Fig. 1.3*b*). This force, owing to the road grip of a tyre, develops wheel motive force F_{wh} equal in magnitude but opposite in direction. The motive force developing on all driving wheels determines total force F, i.e. the *propelling force* of the machine. To move the grader it is necessary that the total motive force exceed the total resistance. The motive force should be variable within a wide range (1 to 10) to suit different conditions of the grader operation.

Motion of the motor grader is ensured by rotation of the driving wheel around the axis under the action of the force F_c applied at a distance R_{wh} which is an arm of the force and is called the *wheel rolling radius*. Product of the force by the arm is termed the moment of force, while the moment of force making a body rotate is called the *torque*.

Designating the wheel torque by T, determine its

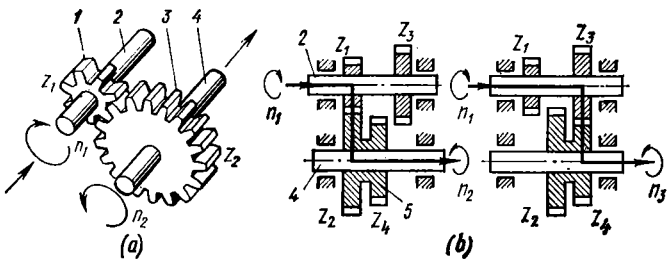


Fig. 1.4. Gear train diagram

(*a*) gear train; (*b*) power flow; *1*, *3*—driving and driven gears; *2*, *4*—shafts; *5*—gear cluster; n_1, n_2, n_3—speed of rotation

magnitude from the known wheel rolling radius R_{wh} : $T = F_c R_{wh}$. Since $F_c = F_{wh}$, find the wheel traction force

$$F_{wh} = T/R_{wh}$$

The wheel rolling radius R_{wh} is substantially constant, therefore the traction force can be changed only by changing the torque T imparted to the driving wheel from the engine of the grader.

The grader engine develops a certain power which is transmitted to the driving wheels. This power is a product of torque T by wheel speed of rotation n_{wh}. Since the engine power is limited, to increase the torque, the wheel speed should be decreased and vice versa.

This function is accomplished by a special *torque converter* (*transmission*) provided between the engine and the wheels. The purpose of the transmission is to transmit and increase the torque imparted to the wheels and to change the driving wheel speed.

To convert the engine torque the motor grader transmissions utilize gear trains. The gear train torque and speed are changed stepwise by varying ratios of gear pairs.

Fig. 1.4*a* shows a gear train comprising two parallel shafts (*2*) and (*4*) carrying gears (*1*) and (*3*) with Z_1 and Z_2 teeth. Gear (*1*) Z_1 is driving, gear (*3*) Z_2 is driven. The ratio of the number of driven gear teeth to that of the driving gear teeth is called the *gear ratio*.

When Z_1 is equal to Z_2, the gear ratio is 1 : 1, the torque and speed of shafts (*2*) and (*4*) are equal. If Z_1 is less than Z_2 the gear ratio is greater than unity, the torque on shaft (*4*) is greater and the speed is lower than those on shaft (*2*) (reducing gear). If Z_1 is greater than Z_2, the gear train is increasing, the torque on shaft (*4*) is lower but the speed is higher. Thus the torque and speed can be changed discretely within the required range by selecting appropriate gear ratios. The gearbox operates on this principle which is illustrated by the diagram in Fig. 1.4*b*. By shifting a gear cluster (*5*) rightward or leftward to mesh its teeth Z_2 or Z_4 with gears Z_3 or Z_1 on shaft (*2*), we can set the shaft (*4*) speed equal to n_2 or n_3, and hence obtain two speeds (gears) of the grader movement.

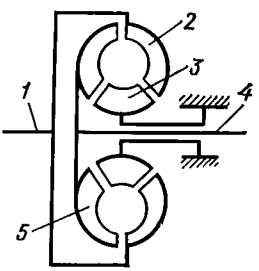


Fig. 1.5. Torque converter diagram

1—engine crankshaft; *2*, *5*—impeller and runner; *3*—reactor; *4*—shaft

The grader transmission comprises all necessary components for transmitting torque from the engine crankshaft to the driving wheels. The motor graders are equipped with *mechanical* and *hydromechanical transmissions*.

The mechanical transmission includes a clutch, a gearbox, and driving axles. It also comprises auxiliary gearboxes and propeller shafts.

The mechanical transmission features a simple design and is highly reliable. However, to improve utilization of the engine power, the number of transmission speeds has to be increased to 6 or 8 which complicates the gearbox design and impedes control of the machine. Using a great number of change gear pairs with different ratios in one gearbox makes it difficult for the operator to choose the right speed, especially at abruptly varying resistance to motion, and leads to frequent gear shifting.

The hydromechanical transmission differs from the mechanical one in that it is fitted with a hydraulic torque converter instead of a clutch.

A torque converter (Fig. 1.5) comprises three bladed wheels,

between which flows hydraulic fluid (oil). The wheel connected to the engine crankshaft is called the *impeller* (*2*). The wheel with its shaft (*4*) transmitting the converter output torque is called the *runner* (*5*). The third wheel, called the *reactor* (*3*), is stationary.

The rotating impeller blades cast oil onto the runner making the latter rotate. A certain inclination of the pump blades makes the oil from the impeller flow in the direction opposite to that of the pump rotation. This, in turn, forces the oil up against the reactor stationary blades resulting in a response force (reaction) of the flow towards the runner. Thus the runner rotates under the action of both the engine torque transmitted with the fluid flow from the impeller and the additional force from the reactor. Therefore, the torque value of the torque converter output shaft may exceed that of the engine's. However, increasing the torque on the runner relative to that on the impeller decreases the runner speed just as increasing torque on the driven shaft of a mechanical gear decreases its speed.

The torque converter is capable of automatically and continuously varying the torque or the motive force and the travel speed of the motor grader according to the total resistance to motion. This, in turn, makes it possible to reduce the number of gears in the gearbox while providing the required range of both the motive force and the travel speed of the machine.

When the torque converter is operating, the rotational speed of the runner is always less than that of the impeller. Such a phenomenon is known as *slip*. It increases with the resistance on the runner shaft. Slip results in energy loss and determines the converter efficiency. With rated slip the efficiency is from 0.8 to 0.85, while increased slip sharply decreases this value. Under maximum load when the runner shaft stops (zero rotational speed), complete slip takes place and the efficiency becomes zero though maximum torque is developed on the shaft.

The ratio between the torques of a fully locked runner shaft and an impeller (engine) shaft is called the *conversion ratio*. This varies from 2.75 to 3.5 determining the range of continuous variation of the drive wheel motive force within one gearbox speed.

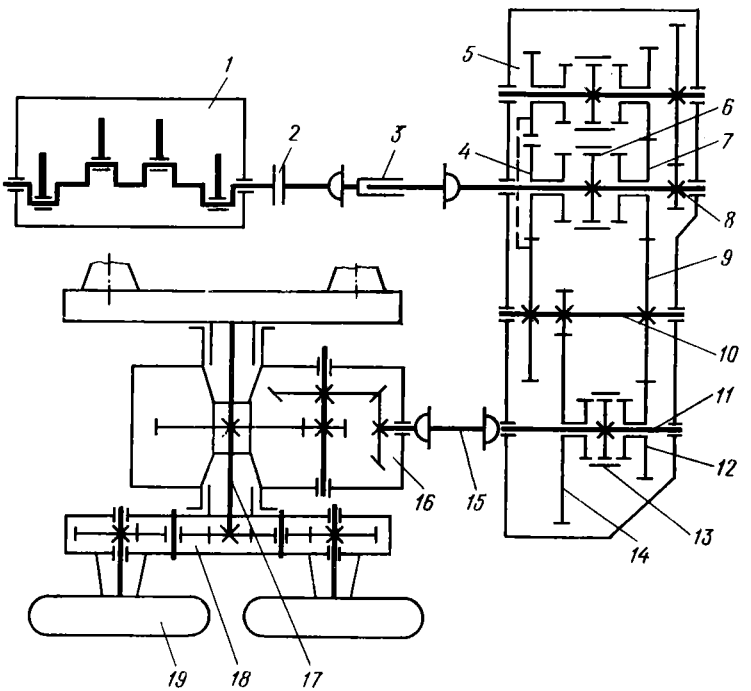


Fig. 1.6. Power train of motor grader with tandem drives

1—engine; *2*—clutch; *3*, *15*—propeller shafts; *4*, *7*, *9*, *12*, *14*—gears; *5*—gearbox; *6*, *13*—gear clutches; *8*, *10*, *11*—input, intermediate and output shafts; *16*—final drive; *17*—half axle; *18*—tandem drive; *19*—driving wheel

The hydromechanical transmission make the operator's job easier while improving the traction performance of the motor grader and its travelling ability. This contributes considerably to the increase of the machine earth-moving output. Also, torque converters damp shock loads imposed on the transmission thereby improving its reliability.

Among major drawbacks of hydromechanical transmissions are the complexity and high cost of construction and operation and increased fuel consumption invoked by them.

Power trains. Interaction of mechanisms ensuring movement of the motor grader is diagrammatically illustrated

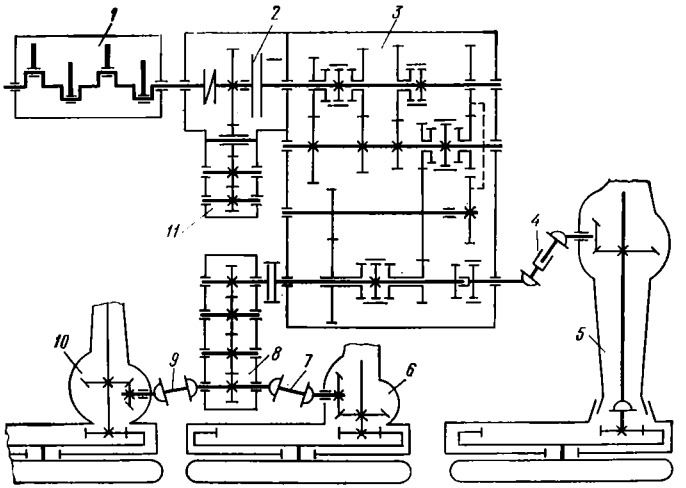


Fig. 1.7. Power train of all-wheel drive motor grader

1—engine; *2*—clutch; *3*—gearbox; *4*, *7*, *9*—propeller shafts; *5*, *6*, *10*—front, middle and rear driving axles; *8*—transfer gearbox; *11*—intermediate gearbox

in Fig. 1.6. Such mechanical diagrams use special symbols to show power flows from the engine crankshaft to the driving wheels of the motor grader.

The crankshaft of the motor grader engine (*1*) transmits torque through the engaged clutch (*2*) and coupling (universal-joint) shaft (*3*) to the input shaft (*8*) of a gearbox (*5*). The shaft (*8*) carries a gear clutch (*6*) engageable with spur gears (*4*) or (*7*) freely running on bearings of the shaft (*8*). When the clutch (*6*) is meshed, say with the gear (*7*), the latter starts rotating jointly with the shaft (*8*). The gear (*7*) meshes with the gear (*9*) to rotate it with its intermediate shaft (*10*) with gears secured on it. By meshing the gear clutch (*13*) with the gear (*12*) or (*14*), torque from the shaft (*10*) is transmitted to the output shaft (*11*). Thus by shifting the gear clutches (*6*) and (*13*) to different positions, it is possible to obtain different rotational speeds of the gearbox output shaft (*11*).

Torque from the output shaft (*11*) is transmitted through the propeller shaft (*15*) to the final drive (*16*) comprising a pair of bevel gears arranged at right angles and a pair of spur gears. Torque from the final drive is imparted via half axles (*17*) and gears of tandem drives (*18*) to driving wheels (*19*). Thus, by varying the rotational speed of the gearbox output shaft (*11*) it is possible to change the rotational speed of the driving wheels, hence the travel speed of the motor grader.

The motor grader whose mechanical diagram shown in Fig. 1.7 is different in that torque from the output shaft of a gearbox (*3*) is transmitted to the rear driving wheels through a gearbox (*8*) and the final drives of the separate driving axles (*6*) and (*10*). Besides, the front axle (*5*) of the grader is also a driving one.

1.2. Classification of Motor Graders

The motor graders are classed according to the following main features: weight, wheel formula, tandem type, transmission type.

Weight of the motor grader substantially determines the construction, performance and principal purpose of the machine as it affects the driving wheel cohesion force, hence the developed motive force. The heavier the motor grader, the stronger the road grip of the tyre and the higher the motive force that can be developed by the grader. According to their weight the motor graders are classed into light-medium and heavy machines.

The wheel formula affects greatly the motive force of the motor grader and its grading capacity. The motor grader wheel formula is $A \cdot B \cdot C$, where A is the number of axles with steerable wheels, B is the number of driving axles, and C is the total number of axles. The motor graders manufactured in the USSR have the wheel formulas of $1 \times 2 \times 3$ and $1 \times 3 \times 3$, which means three-axle motor graders with two or three driving axles. The front wheels are steerable in all graders. The light and medium graders are equipped with two rear driving axles, the heavy ones with all three driving axles.

According to the tandem type motor graders are divided into the following types:

— with fully articulated suspension and tandem drives;

— with fully articulated suspension and separate driving axles.

The first type (Fig. 1.6) is more popular and is used with light and medium motor graders. The rear wheels (*19*) are arranged in pairs at each side of the grader frame and are mounted on the tandem drives (*18*) which in turn are articulated to the case of the final drive (*16*) attached fixedly to the frame. The fully articulated suspension allows substantially unlimited oscillations of the wheels of each side when moving over surface bumps.

The second type (Fig. 1.7) is found only with heavy motor graders. The tandem consists of two driving axles (*6*) and (*10*) interconnected by a fully articulated suspension. Oscillations of wheels at each side is limited by propeller shafts (*7*) and (*9*) which allow only slight tilts in transmitting torque. This type provides for making the grader with substantially identical three driving axles.

The type of the transmission dictates to a considerable extent the design and general performance of the motor grader. The mechanical transmissions of the type shown in Figs 1.6 and 1.7 are the most common.

Some types of graders come with a hydromechanical transmission.

1.3. Basic Specifications

Basic specifications of a motor grader include (Fig. 1.8): structural mass, specific power, blade height and length, travelling speed, clearance, blade pitch or cutting angle, sideshift and penetration, and wheel formula.

Structural mass is the basic parameter which determines the type of the machine and is 9 t for a light grader, 13 t for medium one and 19 t for a heavy grader. The structural mass does not include mass of fuel, lubricants, coolant and braking fluid, spares, tools and auxiliary equipment.

Specific power is the ratio of engine power to structural mass of the motor grader and ranges from 7.36 to 11 kW/t.

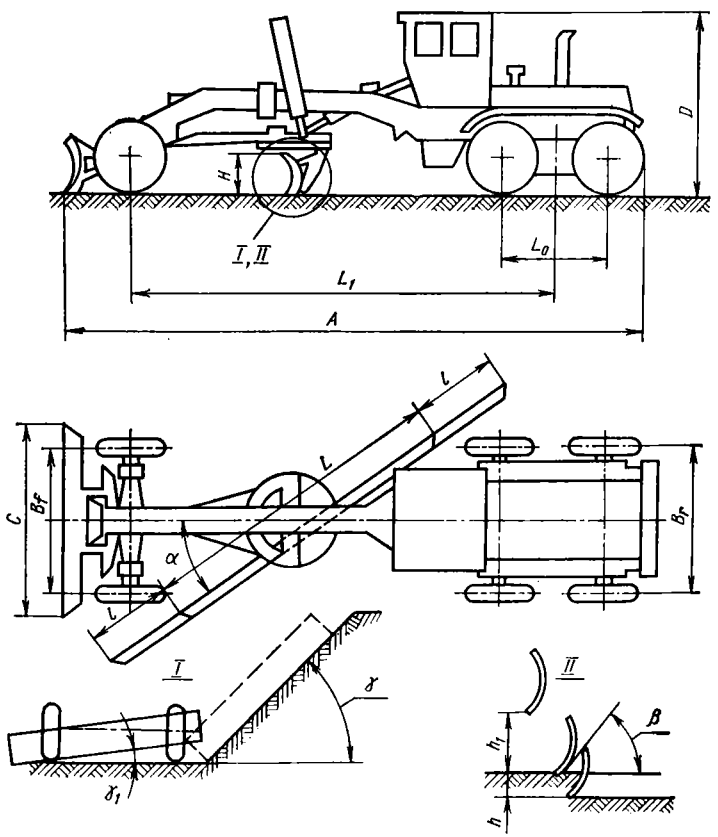


Fig. 1.8. Basic parameters and dimensions of motor grader (*I*, *II*—blade positions)

Blade height H is measured by a chord traced through the cutting edge of the blade and the top edge of the blade front plate.

Blade length L is the distance between its two side edges. The blade length specification does not account for the

length of extensions or wings which are mounted to perform some kinds of work.

Travelling speed is usually up to 4 km/h in earth-moving and at least 35 km/h in travelling.

Clearance h_1 is the distance between the smooth road surface and the cutting edge of the blade lifted to the travelling position.

Blade pitch angle β is measured between the plane extending from the blade cutting edge tangentially to the cylindrical surface of its front plate to the support surface. This angle is adjusted according to the work performed by the machine.

Sideshift l of the blade is the value of longitudinal displacement of the blade from the axis of symmetry of the draft frame in both directions.

Penetration h is the vertical distance measured at the blade cutting edge between the position of the blade on the support surface and its lowermost position.

Wheel formula indicates the number and purpose of the motor grader axles.

Back sloping angle γ is the angle between the support surface and the cutting edge of the blade extended outside the main frame and tilted so that one corner of the cutting edge is on the support surface, while the other is in the uppermost position.

Slope angle γ_1 is similar to the back sloping angle but with the blade being arranged symmetrically to the longitudinal axis of the grader.

Plan angle α is the angle in plan between the blade and the longitudinal axis of the motor grader.

Length, width, height $A \cdot C \cdot D$ are overall dimensions of the grader.

Front and rear tracks B_f, B_r is the distance between planar axes of the left-hand and right-hand wheels.

Overall wheel base L_1 is the distance between the front wheel axis and the tandem oscillation axis lengthwise of the grader.

Tandem wheel base L_0 is the distance between the axes of the tandem wheels lengthwise of the grader.

The basic specifications of the motor graders are given in Table 1.1.

Table 1.1. Basic Specifications of Motor Graders

Characteristics	Specifications		
	light graders	medium graders	heavy graders
Structural mass, t	9	13	19
Height of mouldboard with blade along chord H, mm, min	500-600	600-700	700-800
Blade length less extensions L, mm, min	3000-3700	3600-4350	
Clearance in travelling position h_1, mm, min	300	350	400
Blade pitch angle β, deg		30-70	
Sideshift relative to draft frame l, mm, min	700	800	
Penetration h, mm, min	200	250	350
Back sloping angle γ in both directions, deg		0-70 and more	
Slope angle γ_1, deg		0-30	
Plan angle α, deg		0-90	

Chapter 2

MOTOR GRADER TRANSMISSIONS

2.1. Couplings and Clutches

Couplings are used to transmit torque from the engine to the transmission and ensure resilient connection between the driving and driven members compensating for minor misalignments between the units.

A coupling (Fig. 2.1) is attached to a flywheel (*1*) of the engine. It includes an outer half (*2*), twelve rubber pins (*3*) and an inner half (*6*). The rubber pins enter cylindrical recesses formed by the assembled halves of the coupling. The pins are fixed in the longitudinal direction by two spring rings (*4*).

The most frequent trouble with the coupling is shearing of pins which usually occurs when the engine runs idle at

low speed (up to 500 rpm). To remove the sheared-off pins and install new ones, the ring (*4*) should be removed from the slot through the access hole (*5*).

Clutches are intended to connect the engine crankshaft to and disconnect it from the transmission when changing gears or applying brakes. Also the clutch protects the transmission against overloads owing to slipping of its disks.

A motor grader clutch (Fig. 2.2) is usually of a two-disk normally-engaged type. When changing gears the clutch is disengaged, i.e. its disks are forced apart. The clutch is called dry since torque is transmitted by a compressed stack of disks by dry friction existing in between.

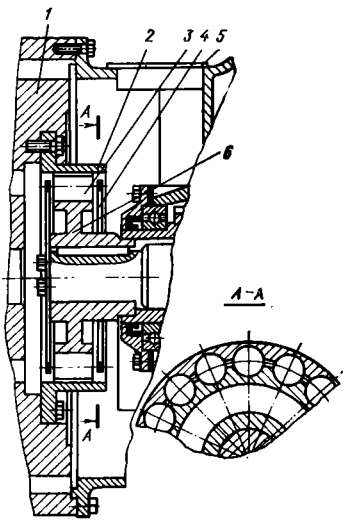


Fig. 2.1. Coupling

1—engine flywheel; *2*, *6*—outer and inner halves; *3*—rubber pin; *4*—ring; *5*—access hole in casing

The driving members of the clutch which transmit torque from the engine are driving disks (*1*) and (*4*) and a pressure plate (*5*). Disk (*4*) and pressure plate (*5*) are connected by dowels with disk (*1*) and are free to move axially for pressing or releasing the driven disks (*3*), thus engaging or disengaging the clutch. The stack of disks is compressed by springs (*13*) and (*14*).

When the disk stack is compressed, torque from the engine is imparted to the input shaft (*11*) of the gearbox through the stack and splined joints of the driven disks and geared the drum (*2*). The disk stack is released by three release levers (*6*) pivoted on the flange (*15*). The lower ends of the levers bear against the slide (*12*) of the release assembly (*9*).

To disengage the clutch, the release assembly is moved towards the brake (*10*) which stops the driven parts rotating freely after the disks are released. This facilitates gear shifting.

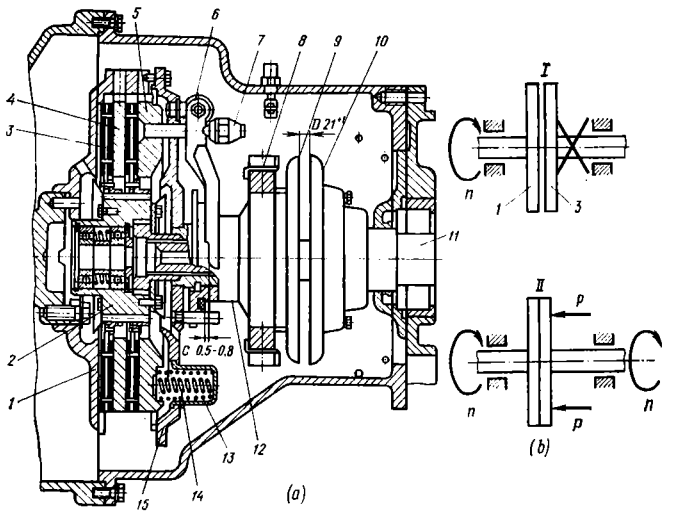


Fig. 2.2. Clutch

(*a*) construction; (*b*) operation diagram; *I*—clutch released; *II*—clutch engaged; *1*, *4*—driving disks; *5*—pressure plate; *2*—geared drum; *3*—driven disk; *6*—lever; *7*—nut; *8*—fork; *9*—release assembly; *10*—brake; *11*—gearbox shaft; *12*—slide; *13*, *14*—springs; *15*—flange; *n*—shaft speed; *P*—pressure

To decrease the clutch pedal force, use is made of a hydraulic booster or servomechanism (Fig. 2.3).

When the clutch is engaged during operation of the motor grader, the rod (*3*) of the servo is in the upper position. Working fluid from the pump of the hydraulic system is fed to the proportioner (*10*) which divides flow *a* into two shown by arrows. One flow is fed to the piston space *D* of the servo and the other to the steering mechanism (cavity *C*).

Oil from cavity *D* flows through passages in the piston to cavity *E* and then to the tank (flow *b*). Pressure in cavity *D* is low, therefore the piston remains stationary. When pushing the clutch pedal linked by a leverage to the rod, the latter lowers with the valve (*2*) thus sealing off by its cone the passages in the piston, hence stopping return of oil from cavity *D* to cavity *E*.

Oil pressure starts rising in cavity *D* and the piston is forced by it to move down pressing the roller (*9*) of the lever

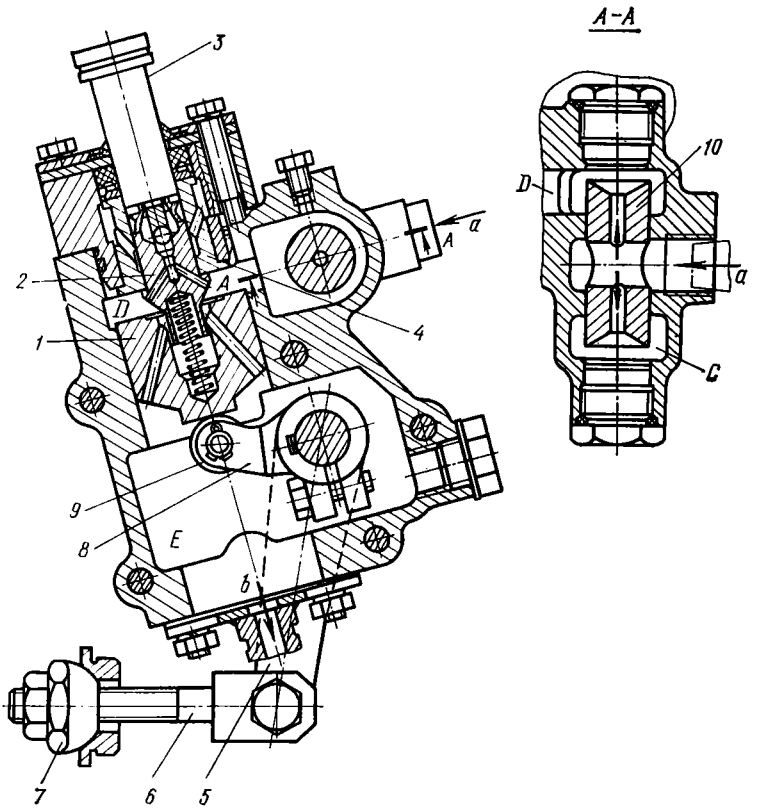


Fig. 2.3. Clutch servomechanism

1—piston; *2*—valve; *3*—rod; *4*—sleeve; *5*, *8*—levers; *6*—rod; *7*—spherical nut; *9*—roller; *10*—proportioner

(*8*) which acts upon the fork (*8*) (see Fig. 2.2) of the clutch release mechanism through the lever (*5*) and rod (*6*).

The clutch disk release moment corresponds to fluid pressure of 1.6 MPa in space *D* (Fig. 2.3). As fluid pressure in space *D* exceeds 3.8 MPa and the rod (*3*) is further depressed, the valve (*2*) opens and oil bypasses to the return line through the holes in the sleeve (*4*) of the valve (*2*).

When the pedal is released, the rod (*3*) returns to the

initial position and the springs (*13*), (*14*) (Fig. 2.2) compress the disks.

If the hydraulic system fails, the clutch can be disengaged mechanically by pushing the piston and roller (*9*) by the rod (*3*) mechanically (Fig. 2.3) but the pedal force rises to 700 N which can be tolerated only in an emergency.

The clutch control mechanism is a system of levers and rods transmitting the force of pressing the pedal in the operator's cab to the servo rod. The clutch pedal is returned to the initial position (clutch engagement) by a return spring.

The clutch is adjusted jointly with the servomechanism according to the following procedure.

Table 2.1. Troubles and Remedies of Clutch and Its Control Mechanism

Trouble	Cause	Remedy
Clutch cannot be disengaged completely (gripping), gear shifting is difficult	Excessive clearance between release levers and release assembly	Set clearance $C=0.5$-0.8 mm (Fig. 2.2)
	Low pressure in servo hydraulic system	Adjust hydraulic system pressure
	Warpage of driven disks or end play of friction linings	Repair or replace driven disks
Clutch slips, grader speed decreases	No clearance between release levers and release assembly	Set clearance $C=0.5$-0.8 mm
	Back pressure under servo piston	Check return line to hydraulic tank
	Oiled disks	Wash disks
	Worn friction facings	Replace disks or facings
	Loosened or broken pressure springs	Replace springs
Release sleeve is short of brake. Gear shifting is impeded	Brake is inoperative for maladjustment of size $D=21$ mm (Fig. 2.2)	Adjust size $D=21$ mm
Clutch pedal does not return to initial position	Loosened return spring	Increase spring tension

Undo nuts (*7*) (Fig. 2.2) and spherical nut (*7*) (Fig. 2.3) and set a distance piece D, 21 mm in size, between the brake disks (Fig. 2.2). Then drive the spherical nut (*7*) in till the piston (*1*) (Fig. 2.3) thrusts against the valve (*2*). Undo the spherical nut (*7*) by eight turns to ensure a clearance of 4 to 5 mm between the valve (*2*) and the piston (*1*).

Besides, the nuts (*7*) (Fig. 2.2) are used to adjust clearance $C = 0.5\text{-}0.8$ mm between the levers (*6*) and the end face of the release assembly (*9*). The servomechanism does not require in-service adjustments.

Troubles and remedies of the clutch and its control mechanisms are listed in Table 2.1.

2.2. Gearboxes

The motor grader gearboxes are intended to change the transmission gear ratio and hence the machine travelling speed and the required driving wheel traction (the operating principle of the gearbox is illustrated in Fig. 1.4*b*).

A gearbox of a light and medium grader with a **mechanical transmission** is shown in Fig. 2.4.

The gearbox comprises a cast iron housing (*23*). An input shaft (*10*) carries gears (*1*), (*4*) and (*5*) which freely rotate on antifriction bearings. Splined between each pair of the gears on the input shaft are gear clutches (*3*) and (*7*).

Gear is selected by means of a slide (*2*) or (*6*) which is moved into engagement with the gear rim to securely fix it to the input shaft. Thus the torque from the input shaft is imparted to the driving gear and then via the driven gear meshed with it to the intermediate shaft (*11*). The intermediate shaft speed depends on the input shaft gear engaged (i.e. on the selected gear).

Gears (*20*) and (*21*) of the intermediate shaft mesh with gears (*16*) and (*14*) of the working and travelling ranges respectively which are mounted on the output shaft (*13*). The ranges are selected by the slide (*15*).

Flanges (*17*) and (*12*) are intended to attach the propeller shaft for connecting the gearbox with the driving axle and to mount the transmission (parking) brake.

The reverse gear of the gearbox is engaged by the gear (*5*) of the input shaft through the gear (*24*) and gear (*21*)

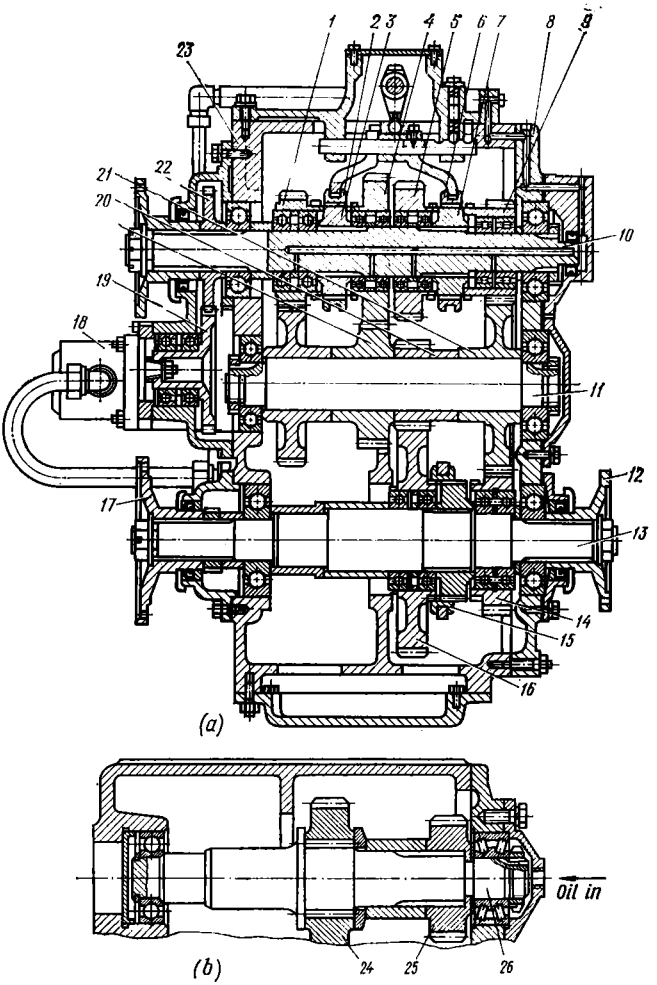


Fig. 2.4. Mechanical gearbox

(*a*) cross-sectional view; (*b*) reverse gear cluster; *1*—second speed gear; *2*, *6*, *15*—slides; *3*, *7*—gear clutches; *4*—third speed gear; *5*—reverse gear; *8*—housing cover; *9*—first speed gear; *10*, *11*, *13*—input, intermediate and output shafts; *12*, *17*—flanges; *14*, *16*, *20*, *21*—gears; *18*—pump; *19*, *22*—driven and driving pump gears; *23*—housing; *24*, *25*—reverse gears; *26*—reverse gear cluster shaft

of the intermediate shaft. The reverse gears (*24*) and (*25*) rotate on the shaft (*26*) installed in the gearbox case. The bearings of this shaft are fed with lubricant from the main system.

The gearbox has three forward gears and one reverse and two ranges—working and travelling. Thus, six forward and one rear gears are provided (Table 2.2).

Table 2.2. Gearbox Ratios

Gear	Working range	Travelling range	Gear	Working range	Travelling range
I	5.7	1.48	III	2.39	0.62
II	5.4	1.14	Reverse	2.56	1.44

The gearbox features forced lubrication of all the input shaft bearings. The lubrication system comprises a gear pump (*18*), suction and delivery pipelines and oil passages for feeding oil from the pan to the axial and radial passages of the input shaft to lubricate its bearings.

The pump is driven by gears (*19*) and (*22*) directly from the input shaft.

The lubrication system pressure is limited by a safety ball valve installed in the housing of the gearbox gearshift mechanism. Other components of the gearbox are lubricated by splashing oil flowing down from the input shaft bearings. Oil is filled into the gearbox case through a filler neck doubling as a level gauge. Oil is drained through a plugged hole in the lower part of the oil pan. To preclude ingress of dirt and abrasion products into the forced lubrication system, a filtering strainer is provided on the pan above the oil intake level. The input and output ends of the shafts with flanges are sealed by self-pressing rubber glands, dust caps and oil slingers.

The gearshift mechanism (Fig. 2.5) is installed on the gearbox case. By manipulating the gearshift lever (*1*) the operator can displace the shaft (*4*) axially leftward and rightward from the neutral position to make the lever secured at the shaft end enter into the slots of forks (*5*) and (*6*).

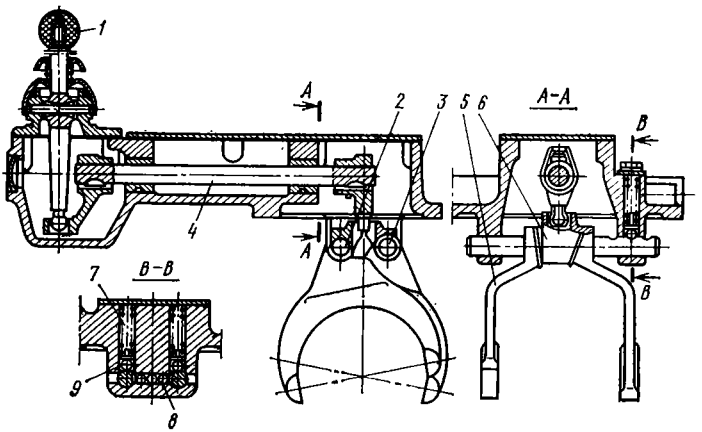


Fig. 2.5. Gearshift mechanism

1—lever; *2*, *3*—shift rails; *4*—shaft; *5*, *6*—forks; *7*—spring; *8*, *9*—balls

Moving the gearshift lever (*1*), the operator turns the shaft (*4*) around its axis thus displacing one of the forks with its shift rail (*2* or *3*) along the axis. This engages the selected gear since the forks displace slides (*2*) and (*6*) (Fig. 2.4) coupled with them.

The fork leftward and rightward travel from the neutral position is limited by retainer balls (*8*) (see Fig. 2.5) which are forced by the spring (*7*) in the respective recesses in the shift rails (*2*, *3*). Each rail has three recesses. To change gears, the operator has to apply a certain force to the lever (*1*) thus overcoming resistance of the spring. This ensures positive locking of the gear, hence of the lever *1*.

To prevent simultaneous displacement of two forks, i.e. engagement of two gears at a time, the mechanism is provided with a special lock comprising three balls (*8*). When one shift rail is slid, the other one is locked with the ball entering its slot.

The range change-over mechanism is arranged on the side of the gearbox case and is constructionally similar to the gearshift mechanism described above. The difference is that the range engagement fork rail has only two recesses for the retainer ball so that there is no neutral position and

the fork can be fixed either in the working or in the travelling position.

The main adjustment points of the gearbox are the gear-shift mechanism and the range change-over mechanism. The purpose of adjustment is to ensure the permissible shift lever force and positive fixation of gears. The retainer ball may get loose in service because of spring weakening. The spring tension is adjusted by means of shims.

Troubles and remedies of a mechanical gearbox are listed in Table 2.3.

Table 2.3. Troubles and Remedies of Mechanical Gearbox

Trouble	Cause	Remedy
Hard shifting	Gripping of clutch, failure of brake	Adjust clutch
	Worn-out meshing part of gear rim and geared slide teeth	Replace worn-out parts
Jumping out of gear	Loosened or broken retainer ball springs	Adjust or replace springs
	Maladjusted rods of gear-shift (range change-over) mechanism	Adjust rod length
Noisy operation	Low oil level in case	Add oil
	Worn-out gear teeth	Replace gear or build up teeth
	Worn-out bearings	Replace bearings
Overheating	Low or high oil level in case	Adjust oil level

Hydromechanical transmission of motor graders (Fig. 2.6) incorporates a torque converter. The *torque converter* of the transmission includes four wheels. Torque from the engine is transmitted through a shaft (*3*) and cover (*5*) of the torque converter to an impeller (*8*). A turbine (*4*) is mounted on an input shaft (*22*) of the gearbox. The stator consists of two wheels mounted on a stationary shaft (*29*) by the overrunning clutches.

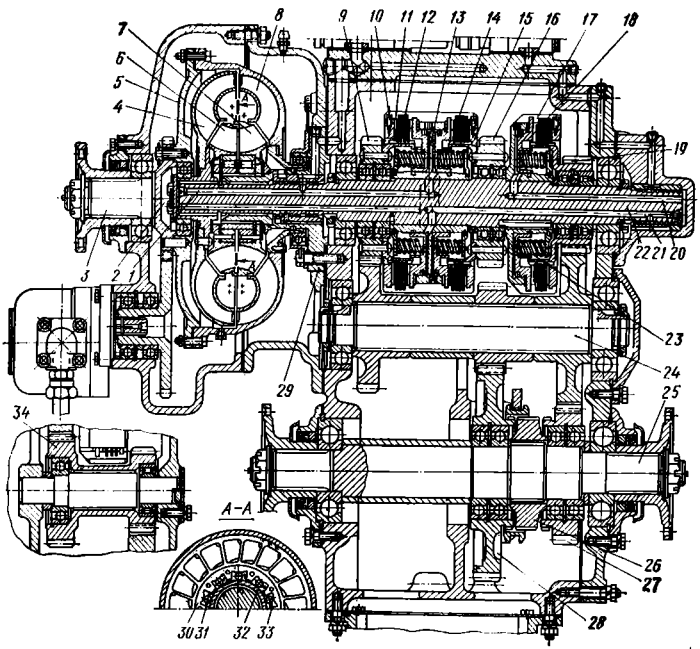


Fig. 2.6. Hydromechanical transmission

1, 20, 21—axial passages; *2, 9, 16, 19*—gears; *3, 25*—input and output shafts; *4, 8*—runner and impeller; *5*—torque converter cover; *6, 7*—reactors; *10, 14, 17*—friction clutches; *11, 12*—driven and driving disks; *13*—housing; *15*—backing plate; *18*—piston; *22*—input shaft; *23*—return spring; *24*—intermediate shaft; *26*—gear clutch; *27*—travelling range gear; *28*—working range gear; *29*—reactor shaft; *30, 32*—outer and inner races; *31*—roller; *33*—spring; *34*—reverse gear cluster

The overrunning clutches comprise outer races (*30*) press-fitted in the reactor wheels, rollers (*31*), springs (*33*) and inner races (*32*) secured to the shaft (*29*).

As the load on the turbine coupled with the grader driving wheels increases, the reactors wheels tend to rotate counterclockwise. In this case, the rollers (*31*) are wedged between the bevelled portions of races (*30*) and (*32*) thus braking the reactor wheels to preclude their turning.

As the load decreases, the rotational speed of the driving wheels, hence of the turbine, increases and at a certain moment when the turbine speed is high the fluid flow emerging

from it changes its direction and tends to turn the reactor clockwise. Now the overrunning clutches release the reactors and all the wheels of the converter start rotating in the same direction functioning as a fluid coupling. This increases the total efficiency of the transmission in travelling.

The gear (*2*) of the input shaft (*3*) is intended to take off power for the gearbox hydraulic system pumps.

The gearbox (mechanical) part of the transmission is unified in some components (case, case cover, intermediate shaft, etc.) with the mechanical gearbox (Fig. 2.4).

The hydromechanical transmission has four forward and two reverse gears (Fig. 2.6).

Torque from the converter turbine is transmitted to the input shaft (*22*) where forward gears (*9*), (*19*) and a reverse gear (*16*) freely run on bearings.

Gears are engaged by hydraulically actuated friction clutches. The friction clutch comprises a housing (*13*) secured on the shaft (*22*), driving disks (*12*) connected with the housing, driven disks (*11*) arranged on the gear rims, piston (*18*), backing plate (*15*) and return springs (*23*).

The friction clutch is engaged from the transmission control hydraulic system. Oil under pressure is fed through passages (*1*), (*20*) or (*21*) in the input shaft into the piston space and compresses the disk stack thus connecting the clutch housing with the gear for transmitting torque to the intermediate shaft (*24*) and then to the output shaft (*25*). The friction clutch is disengaged by releasing oil pressure from the piston space and separating the disks by the springs (*23*). The output shaft has a sliding gear (*26*) for engaging the working (via a gear (*28*)) or travelling (via a gear (*27*)) ranges. The output shaft has flanges for imparting torque to the driving axle and mounting the transmission brake. The reverse gear is engaged through a gear cluster (*34*).

Thus, with two ranges available, two forward friction clutches and one reverse clutch ensure four forward and two reverse speeds: gears I and III are engaged by the friction clutch *17*, gears II and IV by the friction clutch *10* and the reverse gear by the clutch *14*.

The transmission hydraulic system (Fig. 2.7) is intended to feed the working space of the torque converter, engage the friction clutches, lubricate bearings, gears and disks. The

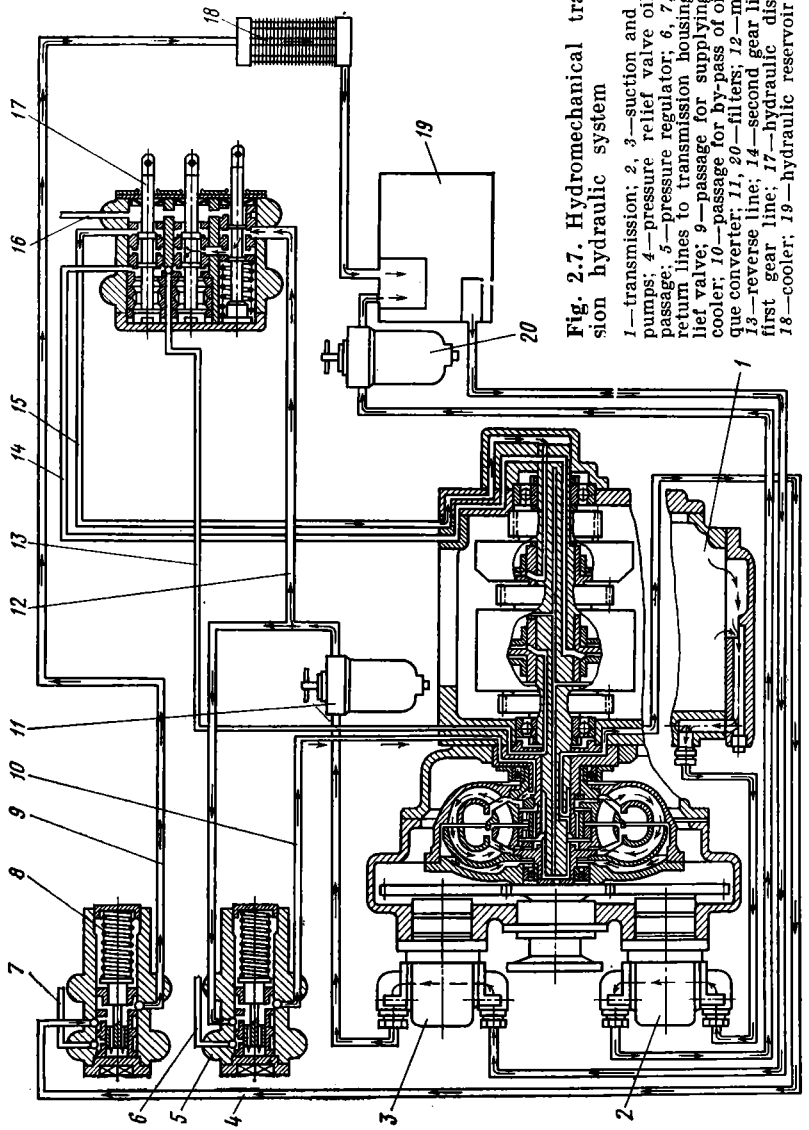


Fig. 2.7. Hydromechanical transmission hydraulic system

1—transmission; *2, 3*—suction and delivery pumps; *4*—pressure relief valve oil supply passage; *5*—pressure regulator; *6, 7, 16*—oil return lines to transmission housing; *8*—relief valve; *9*—passage for supplying oil to cooler; *10*—passage for by-pass of oil to torque converter; *11, 20*—filters; *12*—main line; *13*—reverse line; *14*—second gear line; *15*—first gear line; *17*—hydraulic distributor; *18*—cooler; *19*—hydraulic reservoir

system includes a hydraulic tank (*19*), delivery (*3*) and suction (*2*) pumps, pressure regulator (*5*), relief valve (*8*), gear shifting and reverse hydraulic distributor unit (*17*), filters (*11*) and (*20*), oil cooler (*18*) and pipelines.

All the components of the hydraulic system except the oil cooler, tank and filters are mounted on the intermediate plate of the transmission. The intermediate plate has drilled passages for supplying oil to and returning it from the distributors and valves.

The delivery pump takes oil from the tank and feeds it to the filter (*11*), and then to the distributor (see the arrows in the diagram) and pressure regulator.

The regulator is intended to maintain a pressure of 0.7-0.85 MPa in the main line (*12*) and to bypass oil to the torque converter wheel space via the passage (*10*). When the pressure in the main line rises to 1.1-1.15 MPa, the slide

Table 2.4. Troubles and Remedies of Hydromechanical Transmission and Its Control System

Trouble	Cause	Remedy
Transmission housing overfills with oil and heats excessively	Clogged filter in pan	Remove pan and clean strainer
	Defective suction pump	Replace pump
Excessive pressure in main line	Defective pressure regulator or relief valve	Disassemble and clean pressure regulator and valve
Zero or low pressure in main line and converter feed line	Low oil level in tank	Add oil
	Defective pressure regulator	Disassemble and clean regulator
One of gears cannot be engaged. Oil pressure is normal	Defective hydraulic distributor	Remove, clean and adjust hydraulic distributor
	Defective friction clutch	If it is impossible to shift piston by screwdriver through port in case, disassemble friction clutch
	Clogged hydraulic line	Check feed passages

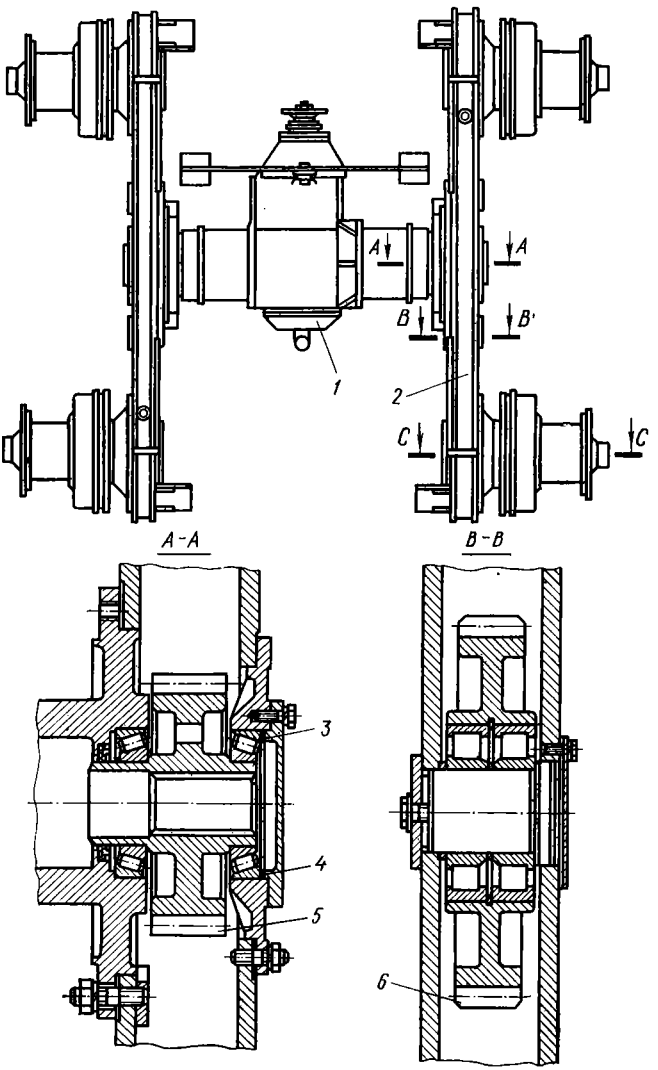


Fig. 2.8. Rear driving axle

1—final drive; *2*—tandem drive; *3*, *12*, *13*—bearings; *4*, *14*—shims; *5*, *6*, *15*—driving, intermediate and driven gears; *7*—bearing seat; *8*—brake disk; *9*—wheel brake; *10*—hub; *11*—nut

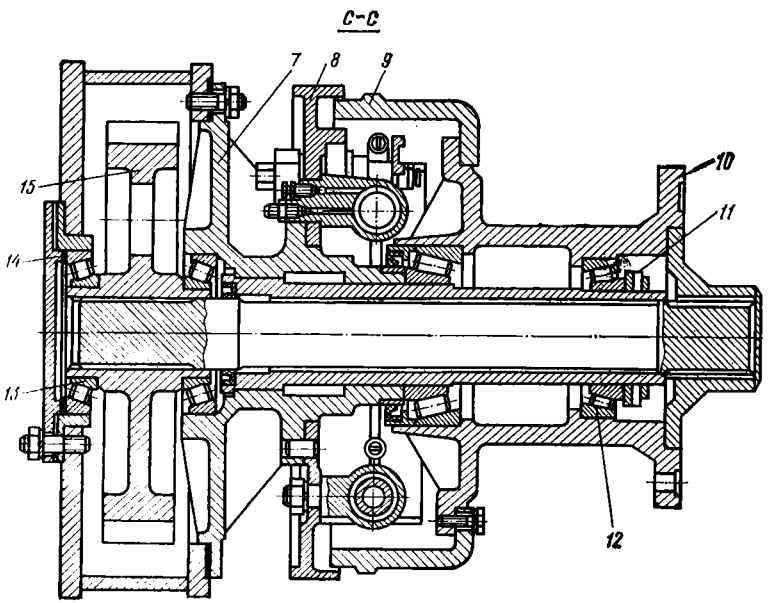
valve of the regulator opens the return line and oil flows to the case through the passage (*6*).

Oil from the working space of the converter flows via passage (*4*) to the relief valve which maintains pressure in the working space between 0.15 and 0.2 MPa and bypasses oil to the oil cooler via the passage (*9*) and then to the tank.

As the pressure in the working space increases to 0.4-0.45 MPa the slide of the valve (*8*) opens the return line and oil flows through the passage (*7*) to the case.

The distributor unit directs oil to the main line and then to the distributors of the forward and reverse gears. When one of the distributors is engaged, the others get connected to the return lines.

Oil fed for lubrication through the passages in the shaft and returned from valves and hydraulic distributors is collected in the case pan and is transferred by the pump (*2*) back to the tank through the filter (*20*).



Troubles and remedies of the hydromechanical transmission are listed in Table 2.4.

2.3. Driving Axles

The driving axles are intended to take up motor grader mass, to increase torque transmitted from the gearbox output shaft and to impart it to the driving wheels. The light and medium motor graders are equipped with fully articulated driving axles.

A rear driving axle of a medium motor grader (Fig. 2.8) includes a final drive (*1*) and tandem drives (*2*).

The two-stage final drive (Fig. 2.9) comprises a pair of spiral bevel gears and a pair of spur gears. Torque from the gearbox is transmitted through the propeller shaft to the first-stage bevel gear (*1*) made integral with the shaft. The gear with the cone of a roller bearing (*10*) and taper bearings (*7*, *9*) are assembled in the sleeve which is secured in the bore of a case (*15*).

Torque from the driving gear is transmitted to a driven bevel gear (*2*) with a shaft (*13*) and then to the second pair of gears (*11*, *14*).

Considerable outward forces develop in the contact area of the bevel gears (*1*, *2*). To preclude deformation of the

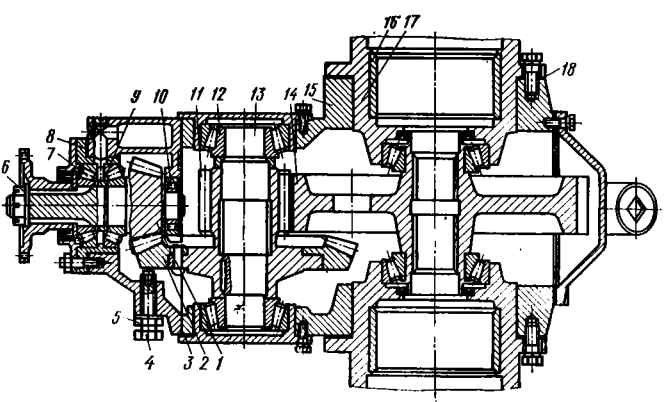


Fig. 2.9. Final drive

1, *2*, *11*, *14*—gears; *3*, *8*, *18*—shims; *4*—limit bolt; *5*, *6*—nuts; *7*, *9*, *10*, *12*—bearings; *13*—shaft; *15*—case; *16*—sleeve; *17*—axle case

rim of the gear (*2*) by these forces a limit bolt (*4*) with a heat-treated end-piece is installed in the case.

The output spur gear (*14*) rests on bevel bearings arranged in the driving axle cases (*17*). The gear (*14*) has internal splines receiving the half axles which transmit torque to the left-hand and right-hand tandem drives. The tandem drives oscillate about axles resting on bronze bushings (*16*).

Torque from half axles is imparted to a driving gear (*5*) of the tandem drive (Fig. 2.8), then via an intermediate gear to a driven gear (*15*) and then through the shaft to a hub (*10*) of the driving wheel.

The housing of the tandem drive is a welded box-shaped structure. The disk of a wheel brake (*9*) is attached to the flange of a bearing seat (*7*).

The gears and bearings of the final drive and tandem drives are lubricated by splashing from the oil bath. Oil is filled through a filler provided in the final drive housing.

Adjustment of the grader rear driving axle is confined substantially to adjustment of meshing between the pair of bevel gears and of clearance in the taper bearings.

Bevel pair meshing (Fig. 2.9) is adjusted by axial relative displacement of the gears. The gear (*1*) is displaced by changing the number of shims (*8*), the gear (*2*) by means of shims (*3*).

The bearings (*7*, *9*) are adjusted by the nut (*6*) with selecting the spacing ring of the required thickness. The bearings (*12*) are adjusted simultaneously with axial displacement of the gear (*2*) with the aid of shims (*3*), and the bearings of the gear (*14*) with the aid of shims (*18*).

The bevel pair adjustment is checked by the paint pattern method. The contact spot at least 30 × 10 mm in size should be at least 2 to 6 mm from the inner edge of the tooth. Bottom clearance should be from 0.2 to 0.5 mm.

Adjustment of the bearings is checked by turning the shaft applying torque of up to 2-6 J. The bevel gear limit bolt is driven in to thrust against the gear end face, backed for $^{1}/_{10}$-$^{1}/_{12}$ turn and locked with a nut (*5*).

Bearings (*3*, *13*) (Fig. 2.8) are adjusted with the use of shims (*4*) and (*14*) according to a similar procedure.

The total torque required to turn the shafts and gears of the tandem drive should not exceed 20-25 J.

The rear wheel taper bearings (*12*) are adjusted with the aid of a nut (*11*) after jacking the axle. The nut is turned on to fully eliminate axial clearance and light jamming of the hub with the brakes disengaged. Then the nut (*11*) is backed for $^1/_6$ turn.

The heavy motor graders have two rear interchangeable driving axles and one front driving axle.

The rear driving axle (Fig. 2.10) consists of the following main components: a load-bearing axle case (*1*), final drive (*31*), wheel brake (*9*) and wheel gearbox (*15*).

Torque is transmitted by the propeller shaft to a flange (*30*) of the final drive shaft with a gear (*29*) and then via a gear (*3*), half axles (*6*), driving sleeve (*11*) and flange (*12*) to the shaft with gear (*14*) of the wheel gearbox. The wheel gearbox consists of internally-meshed gears. The driven gear (*20*) of the wheel gearbox transmits torque via the shaft with hub (*19*) to the driving wheels.

The wheel brakes are installed between the half-axle (*6*) and the driving shaft with gear (*14*) of the wheel gearbox.

The shaft with hub (*19*) is installed in two bearings (*16*, *17*) resting on the wheel gearbox housing (*18*) and wheel brake housing (*23*). The shaft with hub has passages with a nipple (*21*) and cup (*22*) for supplying air from the tyre centralized inflation system.

To disassemble the rear driving axle, use the following procedure: remove the wheel, drive out bolts from joint *I-I* and remove the wheel gearbox with the bracket; withdraw the half axles and the final drive.

The wheel gearbox is disassembled after disassembling the brake, removing the driving sleeve (*11*) and flange (*12*) and driving out cover (*13*) attachment bolts. After driving out the bolts from joint *II-II*, the wheel gearbox is separated from the brake housing (*23*).

The gears and bearings of the driving axle are lubricated by splashing from oil baths in the axle cases and wheel gearbox housing.

Subject to adjustment in the rear driving axle are meshing of the pair of shafts with bevel gears (*29*, *3*) and taper bearings (*4*, *34*).

Prior to adjusting meshing, position the gear (*3*) relative to the housing (*33*) so that the tooth point of the larger gear

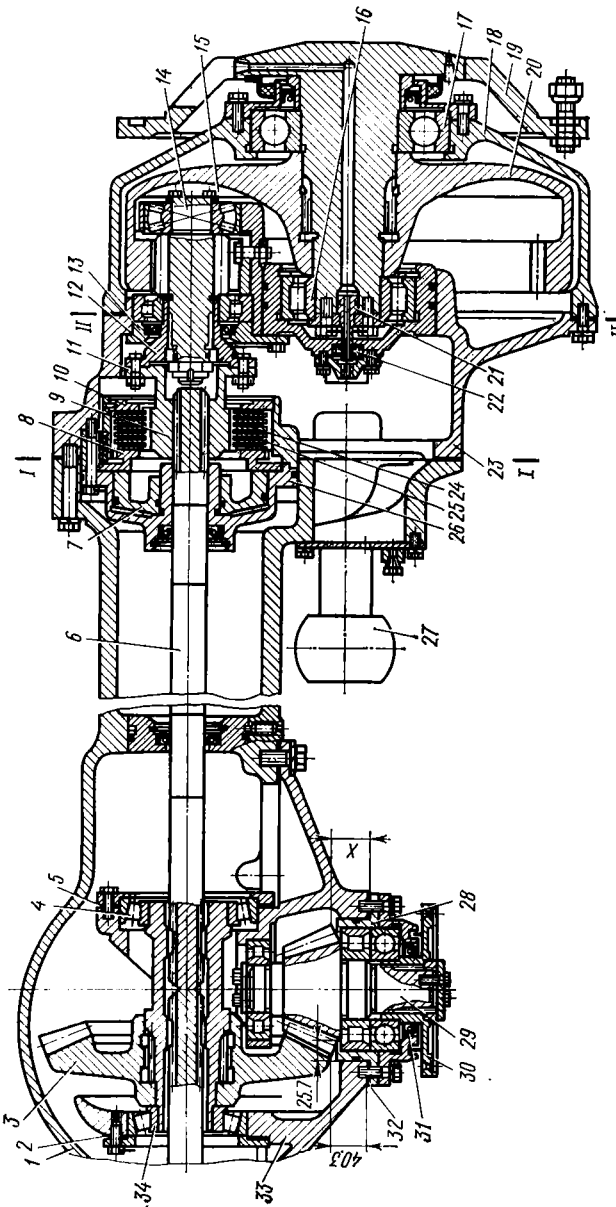


Fig. 2.10. Rear driving axle of heavy motor grader

1—load-bearing axle case; *2, 5, 32*—shims; *3*—bevel gear; *4, 16, 17, 34*—bearings; *6*—half axle; *7*—piston; *8*—pressure disk; *9*—wheel brake; *10*—clutch housing; *11*—driving sleeve; *12, 30*—flanges; *13*—cover; *14, 29*—shafts with gears; *15*—wheel gearbox; *18*—wheel gearbox housing; *19*—shaft with hub; *20*—driven gear; *21*—nipple; *22*—collar; *23*—brake housing; *24, 25*—driven and driving disks; *26*—air cylinder; *27*—ball pin; *28*—sleeve; *31*—final drive; *33*—final drive housing

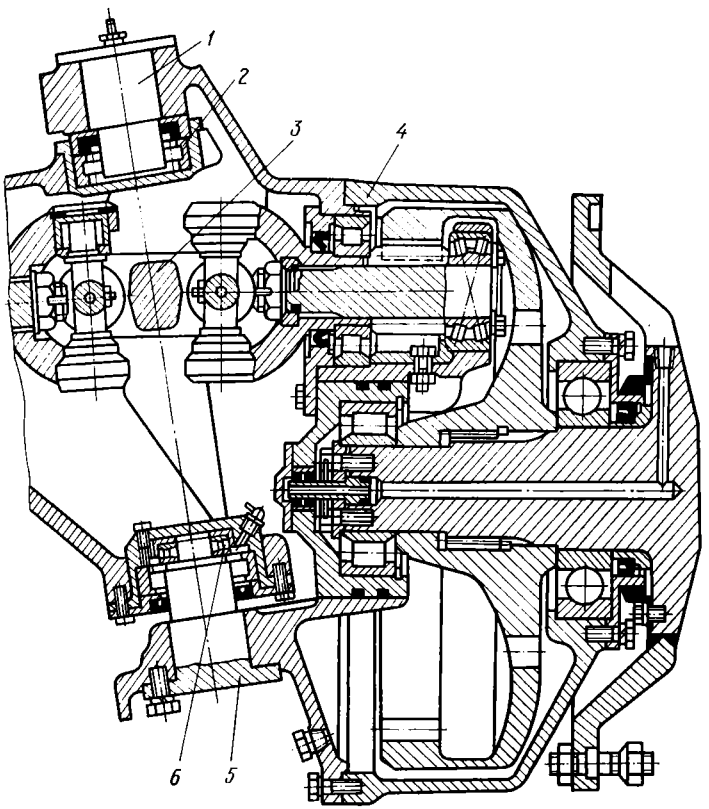


Fig. 2.11. Front driving axle

1, 5—pins; *2, 6*—bearings; *3*—shaft; *4*—wheel gearbox

is 25.7 mm from the edge of the locating hole for the sleeve (*28*) of the shaft with gear (*29*). This is ensured by selecting shims (*2, 5*) simultaneously with adjusting the taper bearings. Then measure size X in the shaft with gear (*29*) between the tooth point on the largest diameter and the mating surface of the sleeve (*28*). Subtract 40.3 mm from the measured value X and determine the required thickness of shims (*32*).

Quality of meshing is checked by operation noise and bearing pattern.

If the final drive is properly adjusted, its temperature under load should not exceed 60-80°C.

The front axle of the heavy motor grader (Fig. 2.11) is both driving and steering. The front axle is unified with the rear one to a considerable extent and is different basically in the steering parts of the wheels which are turned about king pins (*1*, *5*). Torque is transmitted from the half-axle through the steering section of the axle by a double-joint propeller shaft (*3*). The wheel gearbox (*4*) of the front axle is constructionally similar to that of the rear axle. No wheel brakes are provided in the front axle of the motor grader.

The final drive and the wheel gearbox are lubricated likewise in the rear axle. The king pins (1, 5), bearings (2, 6) and the universal joints are lubricated by grease fittings.

The front axle disassembly and adjustment procedure is similar to that of the rear axle.

Troubles and remedies of the driving axles are listed in Table 2.5.

Table 2.5. Troubles and Remedies of Driving Axles

Trouble	Cause	Remedy
Final drive overheats	Low or high oil level	Adjust oil level
	Improper meshing of bevel pair	Adjust meshing
Excessive noise in operation	Improper meshing of bevel pair	Adjust meshing
	Maladjustment (overtightening) of bearings	Adjust bearings
	Low oil level	Adjust oil level

2.4. Propeller Shafts

The propeller shaft is intended to impart the torque from the engine to the transmission and transfer it between separate units of the drive line.

The motor graders use automobile-type propeller shafts.

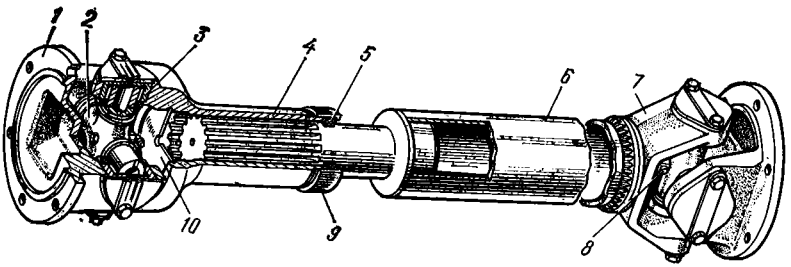


Fig. 2.12. Propeller shaft

1—flange with yoke; *2*—cross; *3*—needle bearing; *4*, *7*—yokes; *5*—ring; *6*—welded shaft; *8*—grease fitting; *9*—cap; *10*—plate

They are similar in design and differ only in dimensions of parts which are determined by the magnitude of the torque to be handled.

The standard-type propeller shaft (Fig. 2.12) comprises two constant-velocity joints interconnected by a slip yoke (*4*) and welded shaft (*6*) with yoke (*7*). The splined slip joint allows for changes of the propeller shaft length thus compensating for unit mounting errors and their displacement, say of the driving axles relative to the transfer gearbox in movement. The torque is transmitted by crosses (*2*) mounted in needle bearings (*3*) in the shaft yokes. The crosses can transmit the torque with the shaft axis inclined relative to the axis of the flange with yoke (*1*).

The slip joint is guarded from soiling by a plate (*10*) on one side and by a sealing ring (*5*) urged by threaded cap (*9*) on the other.

All the propeller shafts are dynamically balanced by the manufacturer. Therefore match marks should be applied to all the parts of the joints before disassembly not to mix them during subsequent installation.

When assembling the propeller shaft, it is necessary to align the arrows stamped on the slip yoke (*4*) and on the shaft (*6*). The yokes (*4*) and (*7*) should be in the same plane. Ignoring this requirement may result in non-uniform rotation of the flanges with yokes at each turn of the shaft and in failure of both the propeller shaft and of the parts driven by it.

Lubricant is fed to the needle bearings and to the splined hole through grease fittings (*8*).

The heavy motor graders use propeller shafts to operate the front driving axle. The drive line includes a system of intermediate and final propeller shafts which are basically similar to those discussed above. Troubles and remedies of propeller shafts are given in Table 2.6.

Table 2.6. Troubles and Remedies of Propeller Shafts

Trouble	Cause	Remedy
Knocks in operation	Worn-out needle bearings	Replace bearings
	Worn-out slip joint	Repair or replace parts
Joints overheat	Lack of lubricant in bearings	Lubricate bearings
Excessive wear of joints	Improper assembly and unbalancing of propeller shaft	Overhaul propeller shaft

Chapter 3

RUNNING GEAR AND OPERATING EQUIPMENT

3.1. Running Gear

The running gear includes a frame, front axles, axle suspension parts, wheels, and tyres.

Grader frame is the main load-bearing structure. It integrates all components of the machine.

A heavy grader frame (Fig. 3.1) comprises three main parts: a front (*8*) backbone beam (*7*) and engine mounting (*2*). The front *8* is a cast structure used to attach the front axle, mounted equipment (scarifier or dozer blade) and is provided with a seat for the draft frame spherical bearing.

The backbone beam (*7*) is made from a round tube. It has side plates (*10*) for attachment of the draft frame sus-

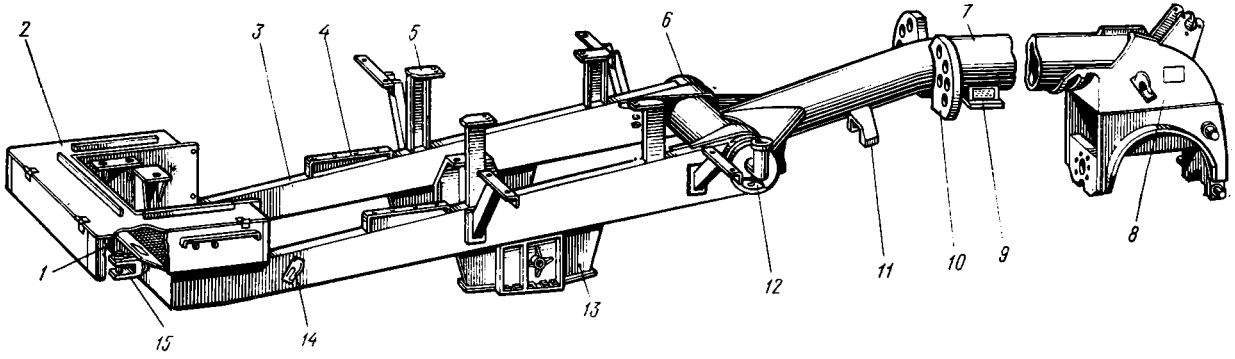


Fig. 3.1. Motor grader frame

1—rear beam; *2*—engine mounting; *3*—longitudinal box beam; *4*—bracket; *5*—cab uprights; *6*—cross tube; *7*—backbone beam; *8*—front; *9, 11*—propeller drive supports; *10*—draft frame attachment side plate; *12*—oil tank filler neck; *13*—axle attachment supports; *14*—mooring hooks; *15*—towing hook

pension mechanism, supports (*9*, *11*) for the front axle propeller shaft. The backbone tube interior is used as a receiver for the pneumatic system of the motor grader. The front end of the backbone tube is welded to the front, while the rear end to the cross tube (*6*) of the engine mounting.

The engine mounting comprises two longitudinal box beams, a cross tube (*6*) and a rear beam (*1*). Welded to the longitudinal and cross beams of the engine mounting are brackets (*4*) for securing the engine with radiators and transmission and uprights (*5*) for the operator's cab. Supports (*13*) for the tandem oscillation axle are welded to the lower part of the longitudinal beams. The interior of the cross tube (*6*) is used as a tank for the hydraulic system of the motor grader.

The frames of motor graders of other types are structurally similar to that discussed above. The basic difference is that the backbone is a box-shaped structure welded from plates.

Front axles of light and medium motor graders are constructionally similar.

The front axle (Fig. 3.2) comprises a wheel (*1*) with a hub (*12*), an axle (*8*), a wheel steering and wheel leaning mechanisms. The axle is attached to the grader frame by a suspension pivot (*4*) which allows oscillation of the axle in the lateral plane within $\pm 15°$ from the horizontal position. The oscillation amplitude is limited by the stops welded to the frame.

The axle (*8*) is a welded box beam with angle braces. Welded to the axle edges are lugs with bores to receive pins for articulating king pins *9* with the axle. The articulated joints provide for leaning the king pins, hence the wheels. To ensure a simultaneous leaning of two wheels the king pins are interconnected by a bar (*5*). Leaning is carried out by a hydraulic cylinder (*7*) having one end attached to the beam of axle (*8*) and the other end to the bar (*5*). The wheel lean is changed from neutral to 20° by adjusting the hydraulic cylinder length.

The wheels are steered about the vertical axis of the king pin (*9*) with the aid of a hydraulic mechanism (not shown) acting upon the king pin arms through forks (*2*) and rods (*3*) forming the steering linkage. The knuckles being the

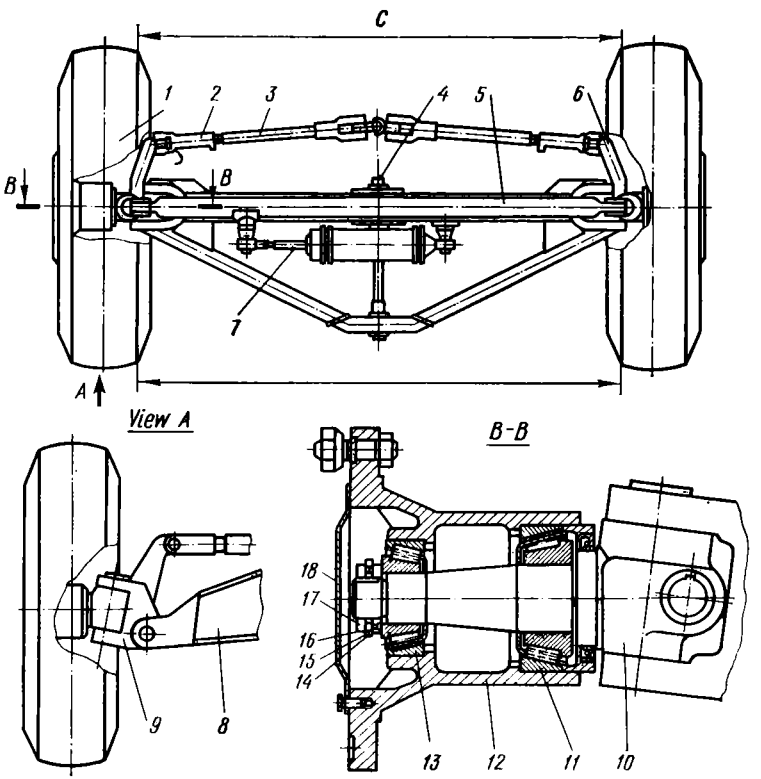


Fig. 3.2. Front axle

1—wheel; *2*—fork; *3*—rod; *4*—axle suspension pivot; *5*—bar; *6*—lever; *7*—hydraulic cylinder; *8*—axle; *9*—king pin; *10*—spindle; *11*, *13*—bearings; *12*—hub; *14*, *17*—adjustment and locking nuts; *15*, *16*—washers; *18*—cap

front wheel axles are installed on the king pins by two bronze bushings. The wheel hub (*12*) freely rotates in bearings (*11*) and (*13*) resting on the knuckle spindles.

Subject to adjustment in the front driven axles of the graders are wheel hub bearings, toe-in and camber.

The tapered roller bearings are adjusted with the aid of a nut (*14*) according to the following procedure. Remove a locking nut (*17*) retaining washer (*16*) and locking washer

(*15*). Turn on the nut (*14*) to fully take up clearance in the bearings so that the hub is slightly braked in rotation. Then back the nut for $^1/_6$ turn and lock it. The hubs are lubricated by packing grease to the cavity covered with a cap (*18*). Toe-in is adjusted by the tie-rod (*3*). Size *C* should exceed size *D* for 5-8 mm. Wheel camber is adjusted by changing the length of the rod of the hydraulic cylinder (*7*). If the adjustment is correct, the wheels should uniformly tilt to both sides from the middle position.

The front driving axle of a heavy grader (Fig. 2.11) is also articulated to the main frame to allow oscillation of the axle housing in the lateral plane of the machine. Contrary to the front axle discussed above, the driving axle has no leaning wheels.

The tandem wheel suspension is considered above (see Fig. 2.8).

The suspension of the rear driving axles (Fig. 3.3) comprises two box-shaped tandem drive housings (*1*) with spherical bearings which accommodate ball pins (*27*) of the axles (Fig. 2.10).

The housings (*1*) (Fig. 3.3) are interconnected by a common axle (*3*) relative to which they oscillate with the axles. The elbow of the axle (*3*) is prevented from turning by a rod (*2*). The suspension is attached to the main frame of the grader by brackets (*4*).

To take up forces tending to turn the driving rear axle about its axis two reactive rods (*2*, *5*) with ball pins are provided. One end of the rod (*5*) is connected to the driving axle housing and the other end to the grader frame.

The heavy grader rear axle adjustment points are the reactive rod ball joints and axle spherical bearings. Clearances in the reactive rod ball joints are taken up by adjustment plugs (*11*) which are first driven fully in and are then backed up to first alignment of the locking holes. Clearances in the axle spherical bearing are eliminated by selecting the thickness of shim stack under the cover.

Pneumatic tyres are highly responsible for the grader performance. Their tread pattern, pressure and construction are vital for machine operation.

A tyre (*1*) includes an inner tube *2* and a flap (*3*) (Fig. 3.4). The tyre is made of rubber and special fabric (cord) of

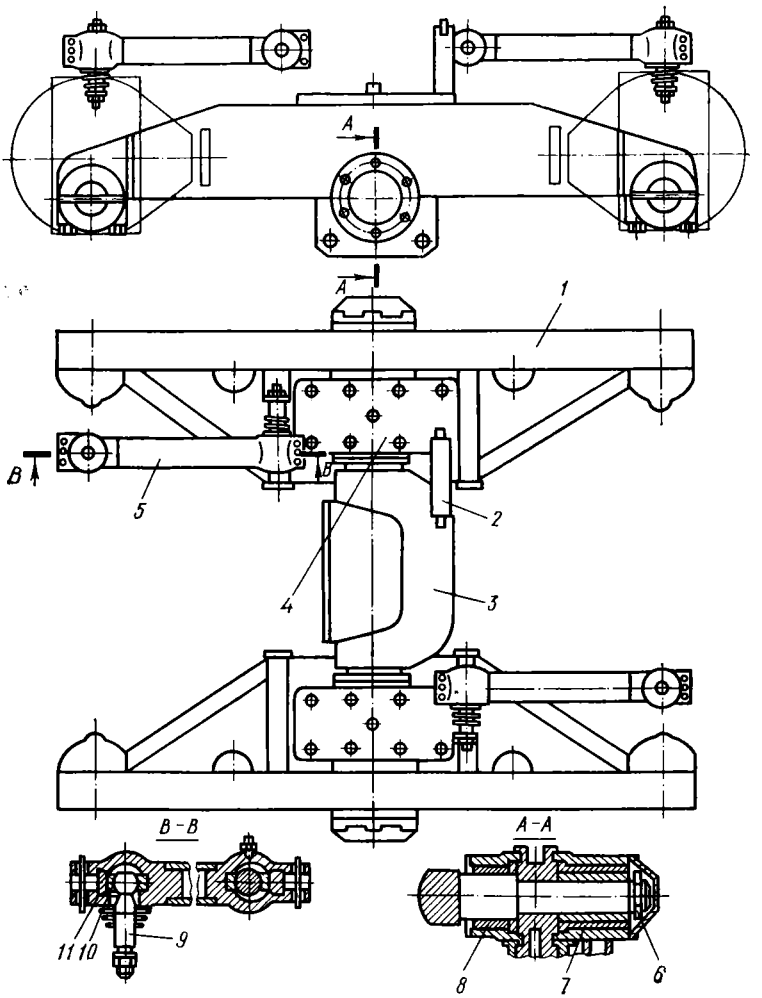


Fig. 3.3. Rear axle suspension

1—tandem drive housing; *2*, *5*—rods; *3*—axle; *4*—bracket; *6*—nut; *7*, *8*—bearings; *9*—ball pin; *10*—block; *11*—threaded plug

cotton and rayon. Modern tyres for motor graders are manufactured with nylon cord offering higher strength and longer life of the tyre.

The flap (*3*) is made from soft rubber. The flap is arranged between the rim (*4*) and the inner tube (*2*) to protect the latter against abrasion by metal when the tyre is deformed under load.

The tyre size designation, e.g. for a heavy motor grader, is 430-610, where 430 mm is the section width (*B*), 610 mm is the inside diameter (*d*). The section height *H* is approximately equal to the section width *B*. The tyre size designation may also be given in inches. For example the same tyre measured in inches is designated as 16.00-24, where 16.00 is the section width and 24 is the inside diameter.

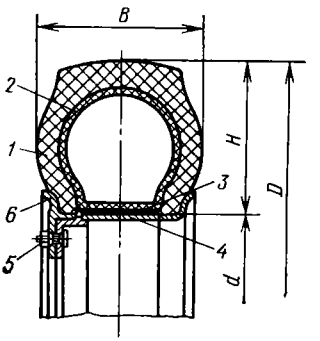


Fig. 3.4. Wheel assembly
1—tyre; *2*—inner tube; *3*—flap; *4*—rim; *5*—nut; *6*—lock ring

Tubeless tyres are also used with motor graders. The basic advantages of such tyres are greater reliability and better safety in case of an accident (the tyres deflate slowly in case of puncture). The valve of the tubeless tyres is attached

Table 3.1. Troubles and Remedies of Tyres

Trouble	Cause	Remedy
Premature wear	Overinflation or underinflation Maladjusted toe-in	Adjust normal pressure Adjust toe-in
Destroyed or broken carcass	Underinflation	Replace tyre
Defective inner tube	Incorrect mounting. Turning of driving axle tyres on rim. Punctured inner tube	Repair or replace inner tube

directly to the rim which eliminates the hazard of its tearing off when the tyre turns on the rim.

Troubles and remedies of tyres are listed in Table 3.1.

The wheel (Fig. 3.4) consists of a rim (*4*) and a lock ring (*6*) pressed to the rim by studs with nuts (*5*). The rim and lock ring have tapered flanges to which the tyre beads are pressed upon inflation.

3.2. Operating Equipment

The main operating equipment of a motor grader includes a blade with a draft frame, draft frame suspension and blade turning mechanism.

The blade with draft frame (Fig. 3.5) is constructionally similar for all the graders. The blade (*12*) is made from sheet steel. The arcuate front sheet is reinforced on the back with sheet box structures. The rear flat sheet has lugs entering slots (*13*) of brackets (*15*) for guiding hydraulically-powered displacement of the blade in both directions. Attached to the front sheet are cutting (*11*) and side (*10*) edges. The brackets (*15*) with the blade (*12*) are attached to a cir-

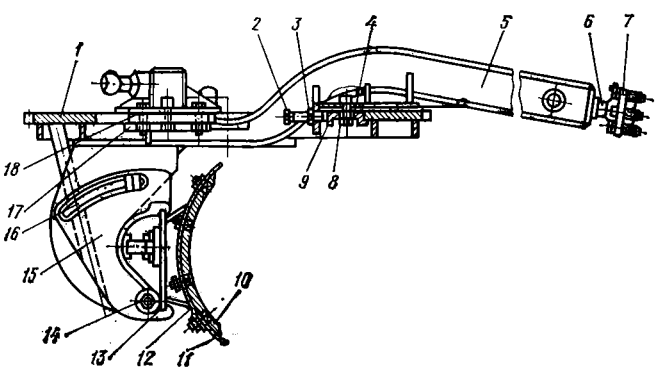


Fig. 3.5. Blade with draft frame

1—circle; *2*, *8*—bolts; *3*—nut; *4*, *18*—shims; *5*—draft frame; *6*—pivot; *7*—support; *9*, *17*—cover plates; *10*, *11*—side and cutting edges; *12*—blade; *13*, *16*—slots; *14*—axle; *15*—bracket

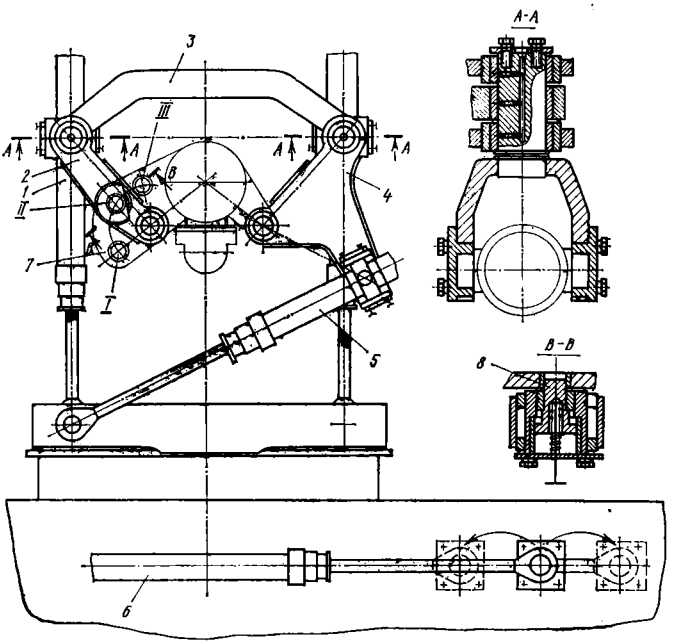


Fig. 3.6. Mechanism for suspending draft frame with 90° blade sideshift

1—blade lifting/lowering hydraulic cylinder; *2*, *4*—left- and right-hand lever; *3*—frame; *5*—draft frame sideshift hydraulic cylinder; *6*—blade sideshift hydraulic cylinder; *7*—bracket; *8*—pneumatic latch; *I*, *II*, *III*—locking holes

cle (*1*) thus forming a single assembly adapted to turn relative to an axle (*14*) within the limits of the slot (*16*) to change the blade pitch angle. The circle provides for turning the blade through 360° in plan in either direction.

The circle (*1*) is attached by cover plates (*9*) and (*17*) to a draft frame (*5*). The cover plate cutout precludes vertical and side displacements of the circle. To ensure free turning of the circle, adjustment shims (*4*) and (*18*) are provided between the cover plates (*9*) and (*17*) which ensure a vertical clearance of from 2 to 3 mm between the cover plates and the circle. The parts are braced by a bolt (*8*). The side clearance between the cover plates and the end face of the circle is adjusted by bolts (*2*) to be from 0.5 to 1.5 mm.

The draft frame (*5*) is a welded structure consisting of a longitudinal and a lateral beams. The lateral beam has points for attachment of the circle and ball pins of the suspension. The front end of the longitudinal beam mounts a pivot (*6*) with support (*7*) for coupling the draft frame with the front of the grader main frame.

All motive force of the driving wheels is imparted to the blade through the ball pivot (*6*). Besides, the pivot should ensure free articulated joint between the draft and the main frames. To achieve it a clearance of up to 0.5 mm is provided in the draft frame pivot-to-pivot seat joint which is adjusted by means of shims. As the clearance increases because of friction surface wear, a shim, 0.5 mm thick, is to be removed from under the pivot support.

The draft frame suspension mechanism makes it possible to sideshift the blade through 90° rightward and leftward for cutting slopes.

Fig. 3.6 illustrates such a mechanism comprising levers (*2*) and (*4*), a frame (*3*) and a pneumatic lock (*8*) secured on the lever (*2*) and hydraulic cylinders (*1*, *5*, *6*) for lifting/lowering the blade sideshifting the draft frame and the blade respectively.

To sideshift the draft frame leftward or rightward, lower the blade turned to a plan angle of up to 30-35° to rest on soil, withdraw the pneumatic lock (*8*) by its cylinder from the lock hole *II* on a bracket (*7*) and manipulating the hydraulic cylinders (*1*) (extending the rod of one cylinder and retracting in the other) bring the draft frame with the blade, frame (*3*), and levers (*2*) and (*4*) to the desired side till the pneumatic lock (*8*) is positively seated in lock holes *I* or *III*. Now lift the blade to the uppermost position and extend it to the desired side by means of the hydraulic cylinder (*6*) and keep on sideshifting the draft frame. Then set the blades to an angle of 90° using the turning mechanism.

The blade turning mechanism (Fig. 3.7) comprises a hydraulic motor (*1*) and a worm gearbox (*2*) (Fig. 3.7). An output shaft (*13*) of the turning mechanism worm gearbox mounts a pin gear (*12*) meshing the teeth of the circle.

The worm gearbox comprises a worm (*5*) and a worm gear (*10*) mounted in sliding bearings (*6*, *8*, *11*). The shaft of

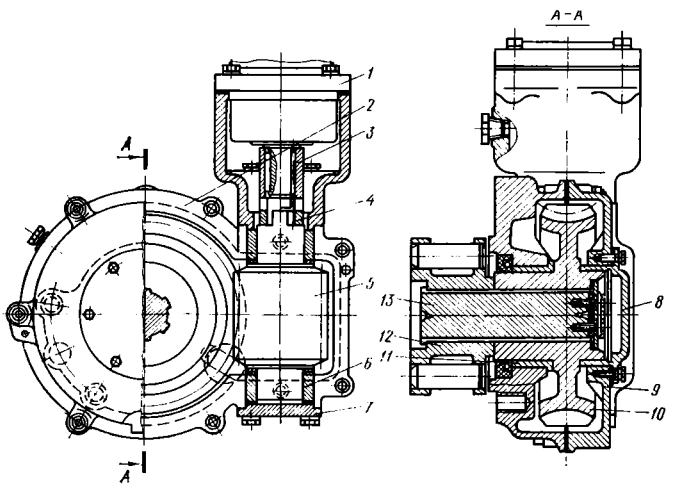


Fig. 3.7. Blade turning mechanism

1—hydraulic motor; *2*—worm gearbox; *3*, *4*—coupling members; *5*—worm; *6*, *8*, *11*—sliding bearings; *7*, *9*—covers; *10*—worm gear; *12*—pin gear; *13*—output shaft

the hydromotor (*1*) is coupled with the shaft of the worm (*5*) by coupling members (*3*) and (*4*).

Adjustment of the worm gearbox resides in ensuring a pin gear clearance of up to 3 mm over the external diameter when a force of 300 N is applied to it. If the clearance exceeds 3 mm, adjust worm meshing by adding shims under the cover (*7*). The axial clearance of the worm gear from 0.05 to 0.5 mm should be adjusted by placing shims under the cover (*9*). If the pin gear clearance cannot be decreased by such adjustments, the worm pair is worn out and should be replaced.

Some graders use gear meshing instead of pin gears in the turning mechanisms.

The auxiliary equipment of the grader includes scarifier, dozer blade, blade extension and replaceable equipment such as back sloper, ditch cleaner and snow plough.

The scarifier is intended to loosen hard layers of soil which are difficult to cut by the blade, scarify gravel and ballast covering in repair of roads and break ice in winter maintenance.

The scarifier of a medium and heavy grader is installed in the forward part of the machine in front of the wheels.

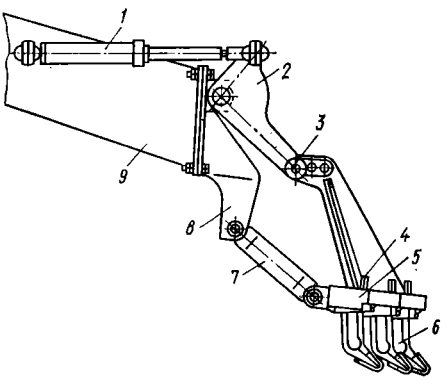


Fig. 3.8. Scarifier

1—hydraulic cylinder; *2*—lever; *3*—retainer; *4*—wedge; *5*—beam; *6*—tooth; *7*—push frame; *8*—bracket; *9*—motor grader frame

It consists (Fig. 3.8) of a cast box beam (*5*) with ports for five teeth (*6*). Welded to the beam are brackets and uprights

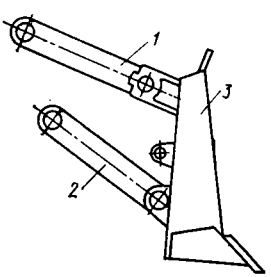


Fig. 3.9. Bulldozer blade

1, *2*—rods; *3*—blade

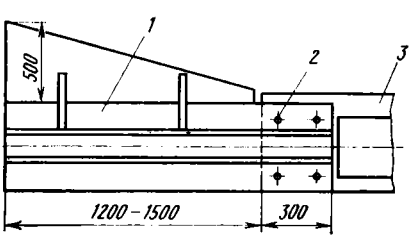


Fig. 3.10. Blade extension

1—extension with widening plate; *2*—mouning parts parts; *3*—blade

to which a push frame (*7*) and a lever (*2*) are pivotally attached. The frame (*7*) and the lever (*2*) in their turn are articulated to a bracket (*8*) bolted to the grader frame (*9*). The teeth are fixed in the beam ports by wedges (*4*). The

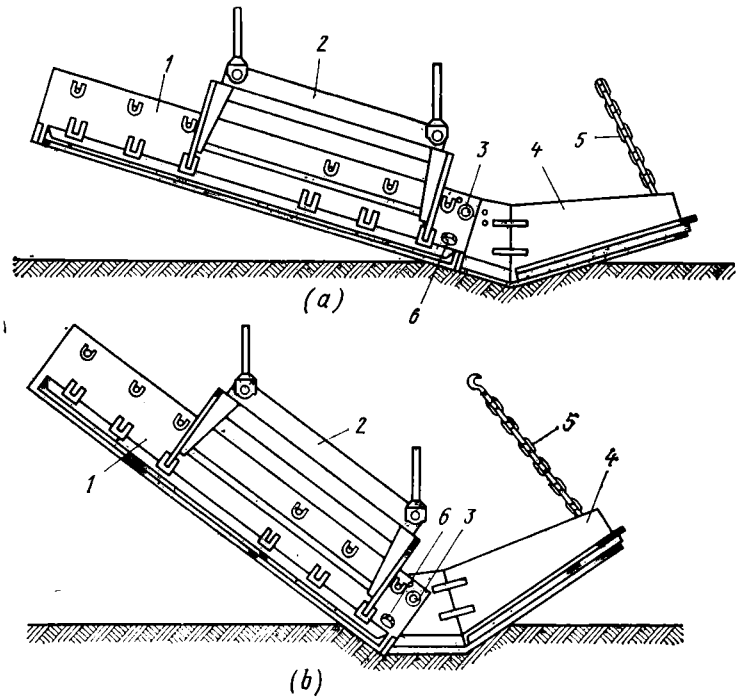


Fig. 3.11. Back sloper

(*a*) for triangular profile; (*b*) for flat-bottom profile; *1*—blade; *2*—draft frame; *3*, *6*—bolts; *4*—back sloper; *5*—chain

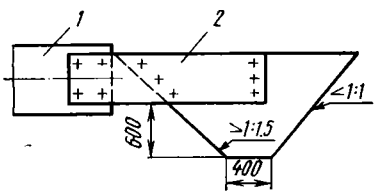
teeth have three slots each to allow varying their height when mounting in the beam, hence the depth of scarifying.

The teeth are hard-faced with a tool alloy. The scarifier is lifted and lowered by means of a hydraulic cylinder (*1*).

Depending on the kind of work to be performed, the cutting angle of the scarifier teeth can be changed in steps of 5° by repositioning a retainer (*3*).

On light motor graders the scarifier is mounted on the draft frame behind the blade. To perform scarifying the teeth are turned downward to the working position. This operation is accomplished with the circle turned through 180° or with the machine moving backwards.

The dozer blade (Fig. 3.9) is used to move soil and other loose materials through small distances for filling ditches, removing construction litter, snow ploughing and other auxiliary construction work which does not require the use of total power of the grader. The dozer blade is mounted instead of the scarifier in front of the grader frame.



Fg. 3.12. Ditch cleaner
1—blade; *2*—ditch cleaner

An extension (Fig. 3.10) is used to extend the blade length to perform operations which do not require utilization of full power of the grader, such as grading and cleaning earth surface and snow ploughing. The extensions increase capacity of the grader by increasing the amount of soil moved during one run.

The extensions are made from sheet steel, 10 mm thick, bent to fit the blade shape and reinforced by angle ribs welded to it. The extensions are bolted to the blade. When using the blade for snow ploughing, a widening plate is attached to the extensions.

A back sloper (Fig. 3.11) is used to cut and trim side ditches. The back slopers are used to form slopes of a triangular and flat-bottom profile. The implement is attached at the

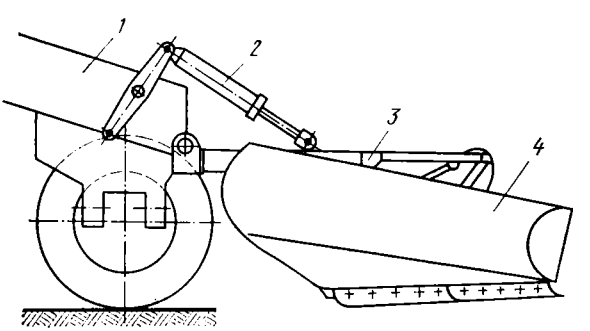


Fig. 3.13. Snow plough
1—motor grader frame; *2*—hydraulic cylinder; *3*—universal frame; *4*—blade

right side by means of a central bolt (*3*) and a fixing bolt (*6*) and is suspended by a chain (*5*) secured to the grader frame.

A ditch cleaner (Fig. 3.12) is intended to clean side ditches of snow. The ditch cleaner is attached to the blade. The ditch cleaner shape follows the side ditch cross section.

A snow plough (Fig. 3.13) includes a blade (*4*) and a universal frame (*3*) hinged to the grader frame (*1*). The snow plough is lifted and lowered by a hydraulic cylinder (*2*). When in use the snow plough rests on two skids which provide for its height adjustments.

The dozer blade and the scarifier are standard items while other equipment is optional.

Chapter 4

BRAKING SYSTEM

4.1. Parking and Service Brakes

The motor graders are equipped with brakes of two types: parking brakes and service (wheel) brakes.

Parking brake. It is installed on motor graders of all types. It is intended to brake the machines at slopes up to 16%, at parking or in an emergency when the wheel (service) brakes are in failure.

The band-type and shoe-type hand mechanical brakes are used with motor graders.

The band brakes (Fig. 4.1) are installed on the output shaft of the gearbox.

A brake drum (*8*) is secured to a flange (*16*) of the gearbox output shaft. The friction band is a steel band (*10*) with asbestos lining (*9*), 8 mm thick, riveted to it and with welded brackets. The band envelopes the drum and is prevented from turning by a bracket (*18*). The free ends of the band are moved away from a bracket (*17*) by springs (*12*). Adjustment bolts (*13*) and (*19*) ensure a uniform clearance between the band and the drum when the brake is released.

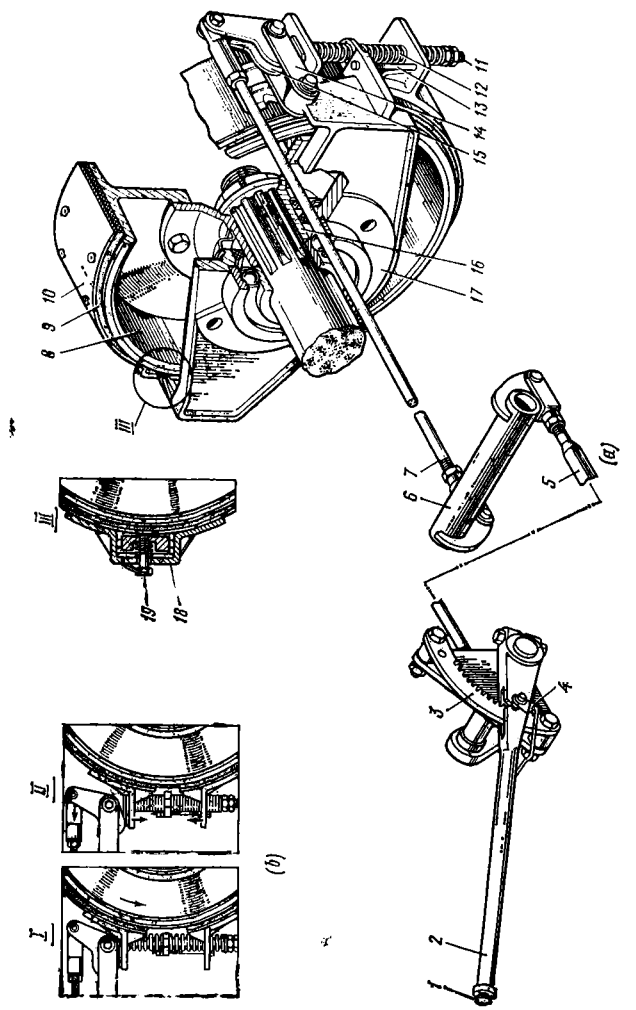


Fig. 4.1. Band parking brake

(*a*) construction; (*b*) working positions; *I*—brake released; *II*—brake applied; *1*—button; *2*—lever; *3*—quadrant; *4*—pawl; *5*, *7*—rods; *6*—shaft; *8*—drum; *9*—lining; *10*—steel band; *11*—coupling screw; *12*—spring; *13*, *19*—bolts; *14*—side plate; *15*—actuator; *16*—gearbox flange; *17*, *18*—brackets

The brake is applied by turning an actuator (*15*) which pulls the band ends together overcoming resistance of the springs (*12*).

Adjustment of the brake consists in setting a clearance of 0.7 to 1 mm between the band and the drum when released and properly locating the brake control lever. The clearance near the support of the bracket (*17*) is adjusted by the bolt (*13*) and the clearance between the lower side of the band and the drum by the bolt (*19*). The nut on the screw (*11*) is intended to adjust the clearance between the upper side of the band and the drum. By changing the length of rods (*5*) and (*7*) ensure that complete braking occurs when a pawl (*4*) of a lever (*2*) is shifted through 5-6 teeth of a quadrant (*3*).

The shoe brake (Fig. 4.2) is mounted on the driving axle final drive housing. Braking force from a lever (*4*) is transmitted to an expander cam (*8*) which expands shoes (*6*) and presses them to a brake drum (*5*) rotating with a flange (*9*) of the driving axle input shaft. Shoe friction force brakes the drum thus braking the wheels through the driving axle final drive. When the lever (*4*) is shifted down, the shoes (*6*) are pulled by springs (*7*) forming a gap between the linings and the drum (*5*). The brakes are adjusted after replacing the linings by changing the length of a rod (*1*) with the lever (*4*) in the lower-most position. No braking should occur when the lever is in such a position.

Low braking force is the main trouble with the parking brake. This may stem from wear or oiling of linings or maladjustment of the brake.

Wheel brakes. These are the main service brakes of the machine intended to decelerate and stop the grader.

The wheel brakes of the hydraulic shoe type (Fig. 4.3) are used on light and medium motor graders.

The wheel brakes are installed on the rear wheels of the grader. They include two shoes (*2*) with linings (*1*) riveted or cemented to them. The upper and lower ends of the shoes are braced by springs. The brake assembly is arranged within a brake drum coupled with the wheel hub (see Fig. 2.8) and securely fixed to the tandem drive housing. Brakes are applied by expanding the shoes and pressing them to the drum with the aid of a wheel cylinder (*4*) (Fig. 4.3)

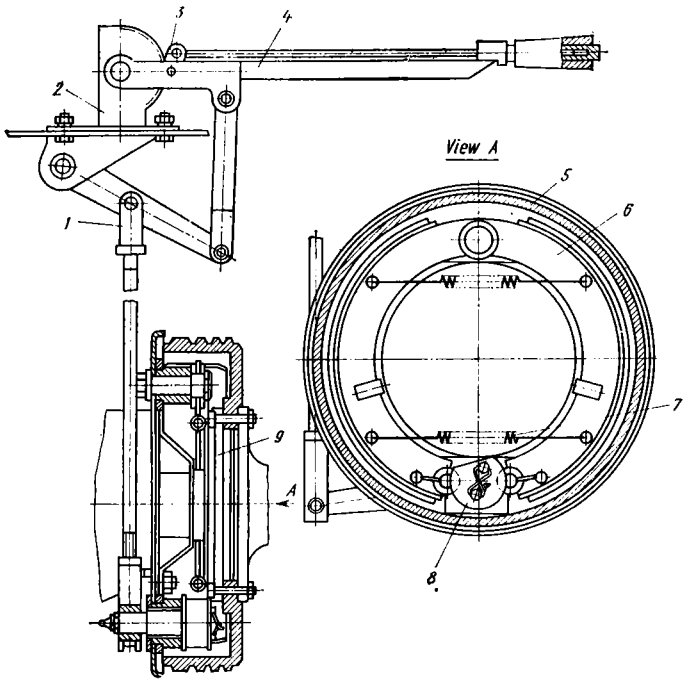


Fig. 4.2. Shoe parking brake

1—rod; *2*—bracket; *3*—pawl; *4*—lever; *5*—drum; *6*—shoe; *7*—spring; *8*—expander cam; *9*—flange

which receives fluid pressure when the brake pedal is depressed.

The brake actuation system (Fig. 4.4) comprises a pedal (*1*), a power unit (*3*) with a master cylinder, a return spring (*2*) and pipelines.

The power unit with the master cylinder (Fig. 4.5) operates as follows. The servo power unit (*9*) is fed with oil from the pump of the motor grader main hydraulic system. When the pedal is released, oil through a connection (*19*) flows through passages (*3*) of the slide valve (*2*) to a connection (*17*) and then to the main hydraulic system. When the pedal is depressed, a pusher (*1*) linked to it by a lever displaces the slide valves (*2*) and (*7*) rightward.

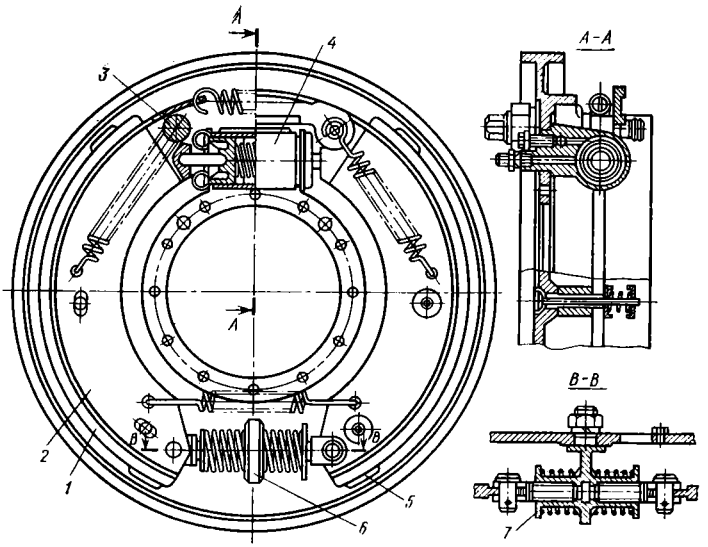


Fig. 4.3. Wheel shoe brake

1—friction lining; *2*—brake shoe; *3*—eccentric washer; *4*—wheel cylinder; *5*—inspection port; *6*—adjuster; *7*—nut

The passages (*3*) are sealed off by a piston (*4*) which remains stationary. Since oil flowing through the connection (*19*) cannot pass through the blocked passages (*3*), pressure rises in the space in front of the piston (*4*) to force the latter with the pusher (*6*) and piston (*10*) of the master cylinder also to move rightward overcoming resistance of a spring (*5*) and opening the passages (*3*). As the pedal is sunk down, the passages (*3*) become fully sealed and oil passes through a safety valve (*18*) adjusted to a pressure of 3 MPa which corresponds to 6 MPa in the space of the brake master cylinder.

When the brake pedal is released, springs (*5*), (*8*) and (*12*) return the slide valves to the initial position.

If the hydraulic power unit becomes inoperative, the pusher (*1*) shifts the slide valves mechanically but the required pedal force increases.

The master cylinder (*11*) operates as follows. The pusher (*6*) displaces the piston (*10*) sealing off the compensating

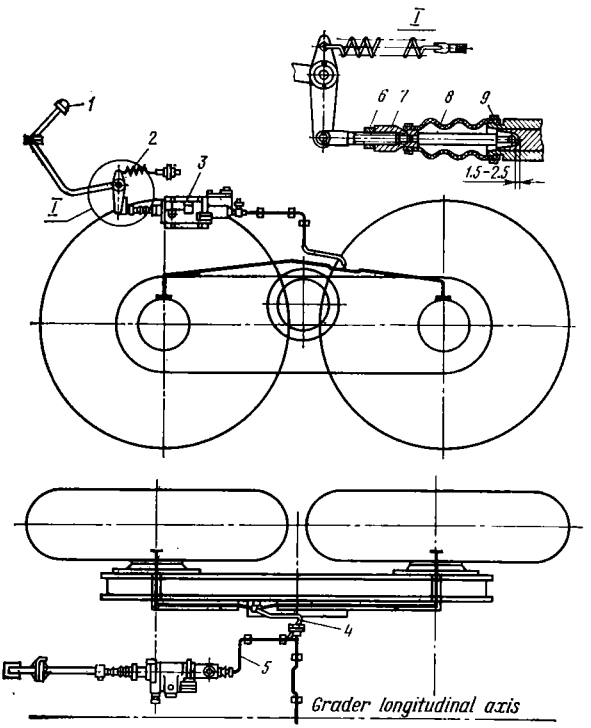


Fig. 4.4. Brake actuation system

1—pedal; *2*—return spring; *3*—hydraulic power unit with master cylinder; *4*—hose; *5*—pipeline; *6*—lock nut; *7*—pusher; *8*—boot; *9*—clamp

port (*15*). Fluid pressure in the working space increases and fluid flows to the wheel cylinders through the valve (*14*). As the pedal is released, fluid is expelled from the wheel cylinders to the master cylinder through the check valve (*13*). The master cylinder has a brake fluid reservoir (*16*). When brakes are applied a part of fluid from the reservoir is fed to the wheel cylinders to return back after the brakes are released.

Subject to adjustment in hydraulic shoe brakes are the clearance between the shoe lining and the drum, the power unit safety valve and the brake pedal free play. The clear-

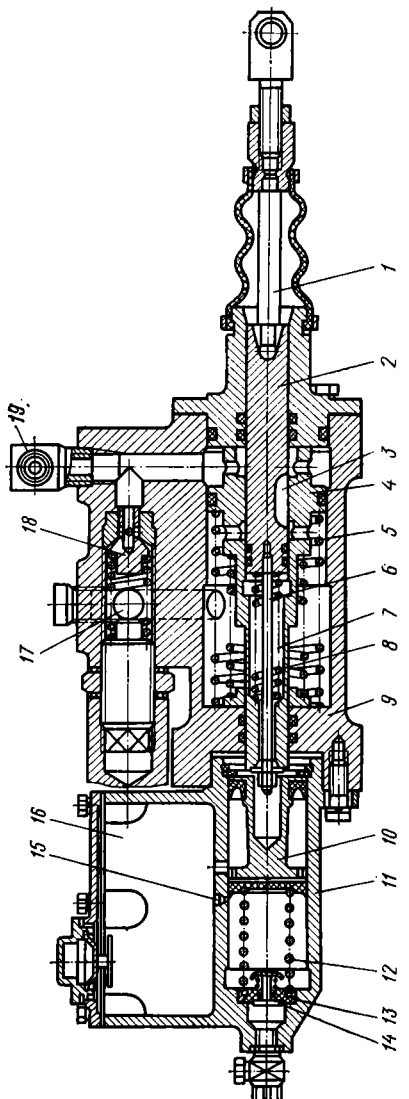


Fig. 4.5. Power unit with master cylinder

1, 6—pushers; *2, 7*—slide valves; *3*—passage; *4, 10*—pistons; *5, 8, 12*—springs; *9*—servo power unit; *11*—master cylinder; *13*—check valve; *14*—release valve; *15*—compensating port; *16*—brake fluid reservoir; *17, 19*—connections; *18*—safety valve

ance should be from 0.2 to 0.5 mm to ensure free rotation of the wheel hub. Such a clearance provides for a complete contact between the linings and the drum. As the linings wear out, the clearance increases. It can be restored by partial and complete adjustment. Prior to adjusting the clearance, check tightening of the wheel hub bearings. The brakes should have normal temperature.

Partial adjustment is carried out by eccentric washers (*3* in Fig. 4.3). To perform the adjustment, jack the rear wheels. While rotating the wheels, turn the eccentric washer of the front shoe till the wheel is braked and then turn it back till the wheel starts rotating freely. The clearance should be from 0.3 to 0.4 mm. Adjust the rear shoe using the same procedure.

A complete adjustment is accomplished after disassembly of the brakes and replacement of worn-out linings. By rotating the nut (*7*) of the adjuster (*6*), adjust a clearance of 0.15-0.2 mm in the lower part of the shoe through the inspection port (*5*) in the backplate. The clearance of the shoe upper part is set to be from 0.2 to 0.5 mm as in the case of partial adjustment.

The safety valve (*18* in Fig. 4.5) is adjusted by a pressure gauge driven into the connection of the master cylinder with the engine idling at minimum speed and the pedal being depressed. Drive in the adjustment screw of the valve to ensure that the pressure gauge reads 3 MPa, then tighten the screw nut and fix the cap.

The brake pedal free play is determined by the gap between the pusher and the power unit slide valve (Fig. 4.4). The gap is adjusted by a threaded joint on the pusher to be from 1.5 to 2.5 mm.

Troubles and remedies of shoe brakes are listed in Table 4.1.

The disk air brakes (see Fig. 2.10) are built in the rear driving axles of heavy graders. Air from the air system rushes to a brake cylinder (*26*), displaces a piston (*7*) and compresses the stack of driving (*25*), driven (*24*) and pressure (*8*) disks. At this moment oil is forced out from the disk chamber through the gaps and return passage to the case.

The driving disks (*25*) have cermet surfaces which ensure

Table 4.1. Troubles and Remedies of Hydraulic Shoe Brakes

Trouble	Cause	Remedy
Low braking efficiency	Maladjusted brakes	Adjust brakes
	Oiled linings	Wash and dry linings
	Air in system	Bleed system
	Fluid leakage	Check system and replace cups
Skidding	Maladjusted brake of one wheel	Adjust brake
	Fluid leakage from one of wheel cylinders	Replace cups
Dragging	Clogged compensation port in master cylinder	Clean and bleed system
	Loosened or broken pull back spring	Replace spring
	Jamming of master cylinder piston	Check piston travel
	Maladjusted clearance between shoes and drum	Adjust clearance

a high efficiency of disk brakes. Steel driven disks (*24*) are splined to a clutch housing (*10*).

When air pressure is released from the piston space, the pressure disk (*8*) is moved backward by the springs to release the disk stack, the disks separate from each other thus ceasing braking.

The advantage of the disk brakes consists in that they require no in-service adjustments, while wear-resistant cermet disks need no maintenance.

4.2. Air Braking System

The air braking system includes a compressor with a pressure governor, a safety valve, a brake valve, pipelines and an air reservoir. Compressed air from the compressor is fed to the air reservoir which is the interior of the longitudinal tube of the motor grader main frame. The reservoir constantly holds the required volume of air and is replenished

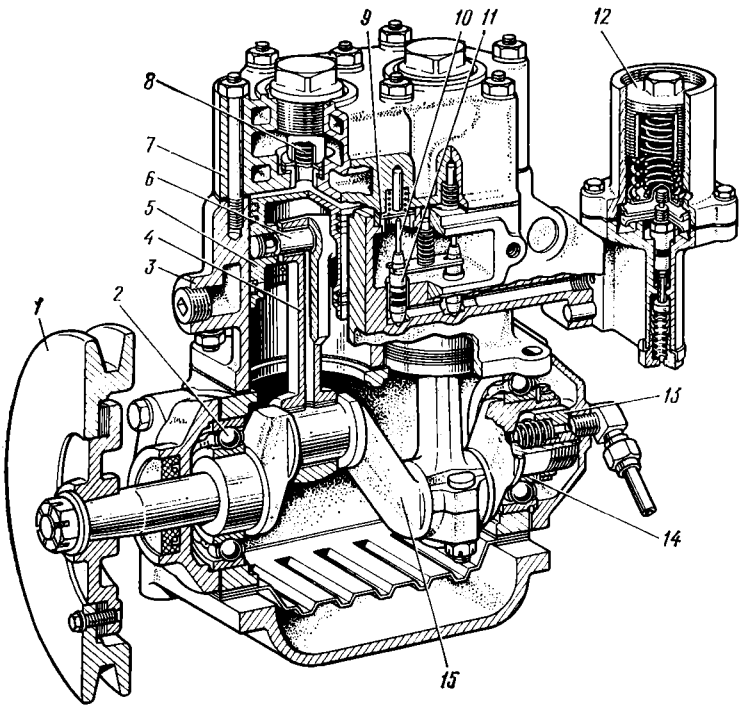


Fig. 4.6. Air braking system compressor

1—drive pulley; *2*, *14*—front and rear crankshaft bearings; *3*—cylinder block; *4*—connecting rod; *5*—piston; *6*—piston pin; *7*—cylinder block head; *8*—pressure valve; *9*—suction valve; *10*—suction valve rod; *11*—suction valve plunger; *12*—pressure governor; *13*—seal with spring; *15*—crankshaft

by the compressor as air is consumed. Air from the reservoir is supplied to the brake valve. When the brake pedal is depressed the brake valve opens admitting air to the wheel brakes.

When the pedal is released, air from the wheel brake lines is discharged through the brake valve to atmosphere.

The compressor (Fig. 4.6) is mounted on the engine and is driven by a V-belt from a pulley (*1*) installed on a crankshaft (*15*). Air through an air cleaner and leaf suction valves (*9*) is sucked into two cylinders of the compressor. Com-

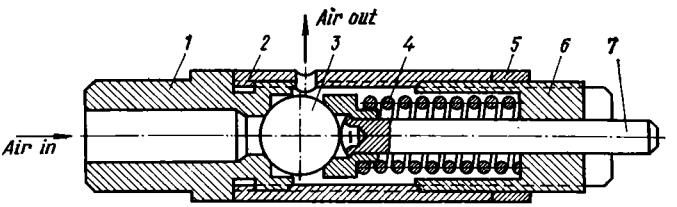


Fig. 4.7. Safety valve

1—seat; *2*—body; *3*—ball; *4*—spring; *5*—lock nut; *6*—adjustment screw; *7*—rod

pressed air is forced into the reservoir through pressure valves (*8*).

A cylinder block head (*7*) accommodates an unloader connected to the pressure governor (*12*). When pressure in the reservoir reaches 0.7-0.75 MPa, air flows through the governor to the unloader, lifts plungers (*11*) and rods (*10*) which open suction valves (*9*). No air is fed to the air system because with the valves (*9*) open air freely flows from one cylinder to another.

As the system pressure drops down to 0.55-0.6 MPa, the pressure governor operates and releases air from the unloader, the valves (*9*) close and air is again delivered to the system.

The compressor is lubricated from the engine lubrication system. Oil is fed through a seal (*13*) and passages in the crankshaft (*15*) and in connecting rods (*4*) to the big end bushes and to the pin (*6*). Bearings (*2*) and (*14*) are lubricated by splashing. The block (*3*) and head (*7*) are cooled from the engine cooling system.

To protect the system against overpressure in case of governor failure a safety valve is installed on the air reservoir. The ball-type valve (Fig. 4.7) is adjusted for air pressure of 0.9 MPa. When the pressure rises, a ball (*3*) overcomes resistance of a spring (*4*), opens a seat (*1*) and releases air to atmosphere through openings in a body (*2*). As air pressure drops down to 0.9 MPa, the spring presses the ball sealing off the seat hole.

The motor graders are equipped with a piston-type brake valve having two cylinders (Fig. 4.8). Only the left-hand cy-

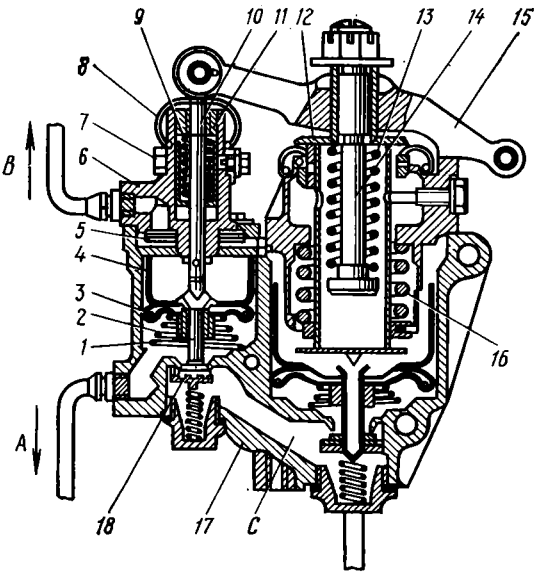


Fig. 4.8. Brake valve

1—rod; *2*—piston return spring; *3*—left-hand cylinder piston collar; *4*—left-hand cylinder piston; *5*—filter; *6*, *12*—left- and right-hand cylinders; *7*—adjustment ring; *8*—left-hand boot; *9*, *13*, *16*—springs; *10*—left-hand cylinder rod; *11*—adjustment nut; *14*—right-hand cylinder rod; *15*—lever; *17*—left-hand cylinder body; *18*—valve

linder (*6*) is used with the braking system. The outlet from the right-hand cylinder (*12*) is plugged.

The brake pedal is linked with the right-hand end of a lever (*15*). When the pedal is released, a rod (*10*) of the left-hand cylinder is urged upward by a spring (*9*). A piston (*4*) is forced by a spring (*2*) to the uppermost position and a valve (*18*) of the left-hand cylinder is pressed by its spring to the seat sealing off a hole in the lower space of the left-hand cylinder body (*17*).

Thus air brake line *A* communicates with atmosphere through a gap between the valve (*18*) and the rod (*1*), and the hollow rod (*1*) via air line *B* which corresponds to released disks in the brake stack.

When the pedal is depressed the right-hand end of the lever

(*15*) moves upward about a rod (*14*) which also lifts somewhat and compresses a spring (*16*), while the left-hand end of the lever (*15*) lowers the tie rod (*10*) and the rod (*1*) so that its lower end contacts the valve (*18*). Now the gap between the hollow rod and the valve is taken up, i.e. the air brake line is disconnected from atmosphere. Further downward movement of the rod (*1*) displaces the valve (*18*) which opens the seat hole thus communicating air lines *A* and *C* of the

Table 4.2. Troubles and Remedies of Air Braking System

Trouble	Cause	Remedy
Brakes do not operate	Air leakage from system	Detect and eliminate leakage
	Defective brake valve	Remove and disassemble brake valve
Low pressure in system	Air leakage from system	Detect and eliminate leakage
	Clogged air filter	Wash filter and replace oil
	Defective pressure governor	Disassemble and wash pressure governor
	Loosened springs of compressor valves	Replace springs
	Loosened compressor drive belt	Adjust belt tension
Air pressure above 0.73 MPa	Defective pressure governor	Adjust pressure governor; if necessary disassemble and wash it
Air pressure above 0.9 MPa	Defective safety valve	Adjust safety valve, if necessary disassemble and wash it
Increased oil content in condensate	Clogged air cleaner of compressor	Wash cleaner and replace oil
	Worn piston rings, oil seal of crankshaft rear end or big end bushes	Send compressor for repair
No air in system	Defective brake valve	Remove and disassemble valve. Troubleshoot and repair it
	Air leakage through loose joints	Trace and eliminate leakage

reservoir or compressor. Such a position takes place when the brakes are applied.

The air brake adjustments are confined basically to setting pressure of air delivered by the compressor. The safety valve (Fig. 4.7) is adjusted by a screw (*6*) compressing the spring (*4*). Driving the screw out decreases and driving it in increases air pressure.

Compressor pressure stability depends on the drive belt tension. The belt sag in the middle between the driving and driven pulleys should be 15-20 mm when a force of 70 to 100 N is applied to it. The belt tension is adjusted by a tension pulley which is shifted in guides by an adjustment bolt.

Troubles and remedies of an air braking system are listed in Table 4.2.

Chapter 5

HYDRAULIC SYSTEM

5.1. General Circuit and Working Fluid

The hydraulic system is intended to control the operating equipment and steer the grader. A typical motor grader hydraulic system is shown in Fig. 5.1.

The system includes two independent closed loops.

The first loop is a system for controlling the operating equipment. The system is fed by a pump (*2*) which takes fluid from a hydraulic reservoir (*1*) and delivers it via a line (*4*) to a hydraulic distributor unit (*5*). Five sections of the hydraulic distributor are linked by lines with double-action hydraulic cylinders (*6*), (*7*), (*10*) and (*8*) intended to lift and lower the blade, sideshift the draft frame and the blade and to control the scarifier. One section of the distributor is connected to a hydraulic motor (*9*) of the blade turning mechanism. The first loop of light and medium graders also includes a front wheel leaning cylinder. Working fluid flowing via a line (*12*) from the hydraulic distributor to the reservoir passes through a filter (*3*).

The second loop is intended to feed front wheel power steering system and the clutch servo (see Sec. 2.1). A pump (*17*)

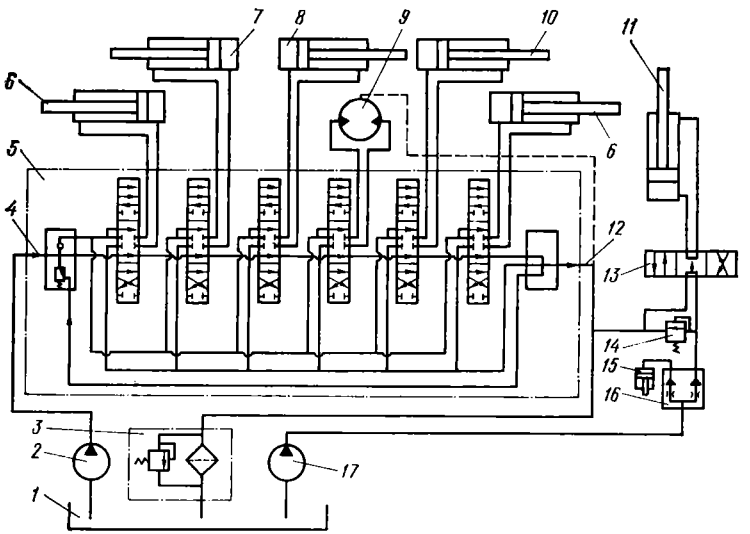


Fig. 5.1. Motor grader hydraulic system

1—hydraulic reservoir; *2*, *17*—pumps; *3*—filter; *4*—line for supply of fluid to hydraulic distributor; *5*—hydraulic distributor; *6*—blade lifting hydraulic cylinder; *7*—draft frame sideshift cylinder; *8*—scarifier cylinder; *9*—hydraulic motor; *10*—blade sideshift cylinder; *11*—steering power unit cylinder; *12*—hydraulic distributor return line; *13*—steering system hydraulic distributor; *14*—safety valve; *15*—clutch servomechanism; *16*—flow divider

of the second loop delivers fluid from the hydraulic reservoir (*1*) to a flow divider (*16*) from which a part of fluid is directed to the clutch servo (*15*) and another part to a steering system distributor (*13*).

Depending on the position of the slide valve in the distributor (*13*) fluid is fed to one of the spaces of the steering power unit cylinder (*11*) or through the filter (*3*) back to the reservoir (*1*).

The system includes a safety valve (*14*) whereby the pressure is maintained within 6-7 MPa. If pressure increases, the valve bypasses fluid to the reservoir upstream of the distributor.

Pressure in the operating equipment control system is set to 10 MPa by a safety valve installed in the distributor delivery section.

Working fluid is filled into the reservoir through a filler with a strainer. The reservoir is provided with a breather connecting the interior with atmosphere, an oil gauge in the form of a dip stick or level plug and a drain plug. Fluid inlet and outlet connections are welded to the reservoir walls.

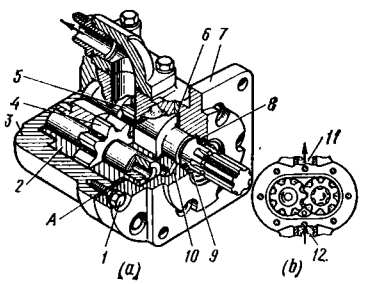


Fig. 5.2. Gear pump

(*a*) construction; (*b*) operation; *1*—bolt; *2*—bush; *3*—body; *4*, *5*—driven and driving gears; *6*—gasket; *7*—cover; *8*—collar; *9*—ring; *10*—by-pass passage; *11*—oil delivery hole; *12*—oil suction hole; *A*—high-pressure space

Working fluid of the hydraulic system imparts pump energy to actuating members (cylinders) and should meet the following requirements: it should have stable viscosity, resist considerable temperature fluctuations without decomposing, be inert to sealing materials, resist foaming. It doubles as lubricant and anticorrodant for units and lines of the system.

All-weather mineral oil is recommended fluid for the motor grader hydraulic system. Using all-weather oils decreases consumption of fluid by eliminating losses during seasonal changes, cuts shipment and storage costs, diminishes the possibility of soiling during filling. It is allowed also to use diesel oils for summer and winter operation, respectively, and spindle oil.

5.2. Construction of Hydraulic System Components

Gear pumps (Fig. 5.2) used on motor graders differ only in capacity.

The pump comprises two constant-mesh spur gears (*4*), (*5*) rotating in borings of a cast body (*3*). The gears are made integral with the shafts resting on bronze bushes (*2*). The bushes doubling as gear end seals are fixed against turning. The necks of the bushes (*2*) are sealed in a cover (*7*) by a gasket (*6*) and the shank of the driving gear (*5*) extends through a collar (*8*) pressed by a retaining ring (*9*). The joint between the cover (*7*) and the body (*3*) is also sealed with the gasket (*6*).

Table 5.1. Troubles and Remedies of Gear Pumps

Trouble	Cause	Remedy
Operating member of motor grader lifts slowly or does not lift at all with serviceable hydraulic distributor and lines	Fluid leakage through sealing gasket (*6*)	Replace gasket
Foaming in reservoir	Suction of air through collar (*8*), sealing ring of suction duct or pipe-to-connection joints	Replace collar or sealing ring in suction duct, check tightening of line union nuts
Increased level of lubricant in adjacent cases whose surfaces mount pump	Fluid leakage through collar (*8*) into case	Replace collar
Fluid leaks through body-to-cover joint	Loosened cover-to-body attachment screws	Tighten screws
	Worn sealing gasket (*6*)	Replace gasket
Excessive noise in operation	Low level of fluid in reservoir	Add fluid

Such a sealing prevents the fluid flowing from a high-pressure space *A* communicating with the delivery space of the pump body. Fluid pressure in space *A* forces the end faces of the bushes (*2*) towards the end faces of the gears closing the end faces of the bushes (*2*) on the other side of the gears to the end face of the boring in the body (*3*).

Thus a seal is formed between all the internal end faces of the pump parts. The higher is the pressure in the delivery space the greater is the force applied to the end faces.

To relieve the collar (*8*) the space in front of it is connected to the suction space of the body (*3*) by a passage (*10*). Thus fluid seeping into the space before the collar is removed to the suction space.

The pump is driven through a splined shank of the driving gear (*5*). Working fluid is fed to and from the suction and de-

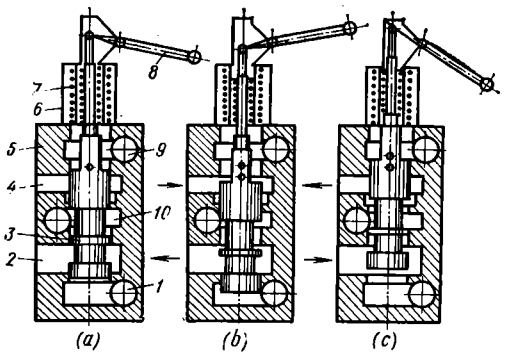


Fig. 5.3. Operation of hydraulic distributor section

(*a*) LOCKED position; (*b*) LOWER position; (*c*) LIFT position; *1*, *2*, *4*, *9*, *10*—spaces; *3*—slide valve; *5*—body; *6*—hood; *7*—spring; *8*—handle

livery spaces via holes (*11*) and (*12*) located on the machined surfaces of bosses on the body (*3*).

The pump requires no in-service adjustments. Troubles and remedies of gear pumps are listed in Table 5.1.

The hydraulic distributor is a control unit of the hydraulic system. It is intended to change direction of fluid flow from the pump to the operating equipment actuators: cylinders or a hydraulic motor.

The motor graders may be equipped with a single-block distributors or the distributors made up of separate sections, which operate on the same principle.

A distributor section (Fig. 5.3) comprises a slide valve (*3*), a body (*5*) and a control handle (*8*) with a lever extending through a hood (*6*) with springs (*7*). An axial opening is made in the body (*5*) and passages from the branch spaces are connected to it. A space (*10*) connects the distributor section with the pump. Spaces (*2*) and (*4*) are intended to supply fluid to the hydraulic cylinders or motor, spaces (*1*) and (*9*) connect the distributor to the return line connected to the reservoir.

In the LOCKED position (Fig. 5.3*a*), the bands of the slide valve (*3*) seal off passages for supply of fluid from the pump space (*10*) to the spaces (*2*) and (*4*) and return of it through the spaces (*1*) and (*9*). Now working fluid is locked

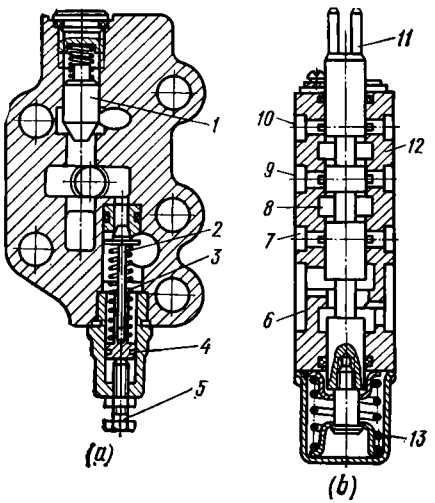


Fig. 5.4. Hydraulic distributor

(*a*) delivery section; (*b*) operating section; *1*—non-return valve; *2*—safety valve; *3*—spring; *4*—piston; *5*—adjustment bolt; *6*—common return space; *7*, *9*, *10*—hydraulic cylinder return spaces; *8*—space for delivery of oil to hydraulic cylinder; *11*—slide valve; *12*—body; *13*—spring

in the hydraulic cylinder or motor and the controlled member is stationary. Fluid delivered by the pump is returned to the tank.

In the LOWER position (Fig. 5.3*b*), the slide valve (*3*) is lowered admitting fluid from the pump space (*10*) through the space (*2*) to one of the spaces of the actuating cylinder. As the cylinder rod displaces fluid from the cylinder other space, it is forced into the space (*4*) of the distributor and flows through the opened passage to the space (*9*) and then to the return line.

When the slide valve (*3*) is lifted (Fig. 5.3*c*) similar events take place in the opposite spaces. Thus the hydraulic distributor ensures reciprocation of the cylinder rod or reversible rotation of the hydromotor.

The sectional distributor integrates the delivery, operating and return sections into one unit.

The delivery section (Fig. 5.4*a*) is intended to supply fluid to the operating sections. It is provided with a safety valve (*2*).

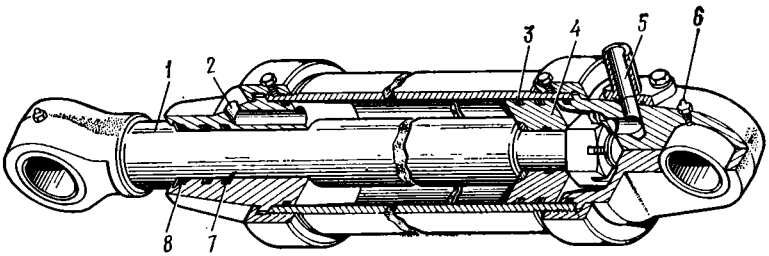


Fig. 5.5. Hydraulic cylinder

1—rod; *2*, *5*—oil passages; *3*—piston seal; *4*—piston; *6*—grease fitting; *7*—rod seal; *8*—dirt stripper

If the delivery line pressure exceeds a preset limit (e.g. 10 MPa), working fluid overcomes resistance of a spring (*3*), opens the valve (*2*) and returns to the reservoir thus bringing the pressure back to the normal value.

A check valve (*1*) built in the delivery section prevents counterflow of fluid from the hydraulic cylinders to the delivery line and leakage from cylinders to the transfer passages during engagement and disengagement of the distributor.

The operating section (Fig. 5.4*b*) is similar to that shown in Fig. 5.3.

The operating section includes a through space (*6*) which defines a common return passage through all the sections with the slide valve (*11*) in the LOCKED position.

When the slide valve of any section moves upward or downward, the common return space (*6*) is sealed off and fluid goes to the respective space (*8*) of this section and then to the respective actuating mechanism.

The operating section slide valve is controlled and kept in the working position manually. It is returned to the LOCKED position under the action of a spring (*13*).

Adjustment of the hydraulic distributor consists in limiting the operating pressure by means of a safety valve. The value is adjusted by a bolt (*5*) pressing a piston (*4*) with a spring (*3*). To check pressure, connect a pressure gauge to a line of any operating member, cut in the distributor and bring the cylinder rod to the stop.

Hydraulic cylinders (Fig. 5.5) of the motor graders are of

the standard type. These are double-action actuators, i.e. they can displace the rod and transmit force in both directions.

The cylinder space accommodating a rod (*1*) is called a rod space, while the space in front of a piston (*4*) is called a piston space. Fluid is fed to and expelled from the cylinder spaces through passages (*2*) and (*5*). To prevent leakage of fluid

Table 5.2. Troubles and Remedies of Hydraulic Cylinders

Trouble	Cause	Remedy
Cylinder develops insufficient force	Defective piston seal, leakage of fuel between spaces	Replace seal
Oil leaks through rod	Defective seal in cylinder piston cover	Replace seal

between the spaces the piston (*4*) is provided with rubber seals (*3*) and the rod (*1*) with seal (*7*). Besides, there is a dirt stripper (*8*) which removes dirt from the rod when the latter is retracted into the cylinder.

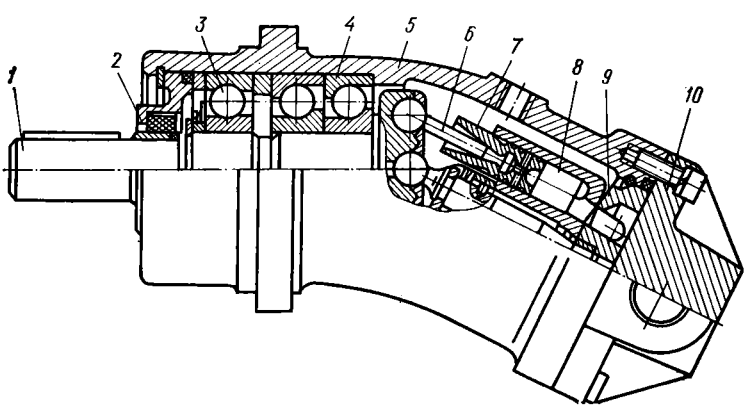


Fig. 5.6. Hydraulic motor

1—shaft; *2*, *10*—covers; *3*, *4*—ball bearings; *5*—body; *6*—connecting rod; *7*—piston; *8*—cylinder block; *9*—hydraulic distributor

Troubles and remedies of the cylinders are listed in Table 5.2.

Swash-plate hydraulic motors (Fig. 5.6) are used to actuate the blade turning mechanism.

Working fluid is fed via passages in a body (*5*) and in a distributor (*9*) to a cylinder block (*8*). Fluid pressure moves a piston (*7*) in the axial direction and the force is transmitted through a connecting rod (*6*) to the flange of a shaft (*1*). This force is resolved into axial and tangential components in the joint between the ball end of the connecting rod (*6*) and the spherical seat in the flange of the shaft (*1*). The axial component is taken up by radial thrust ball bearings (*4*), while the tangential component creates torque which causes rotation of the shaft (*1*).

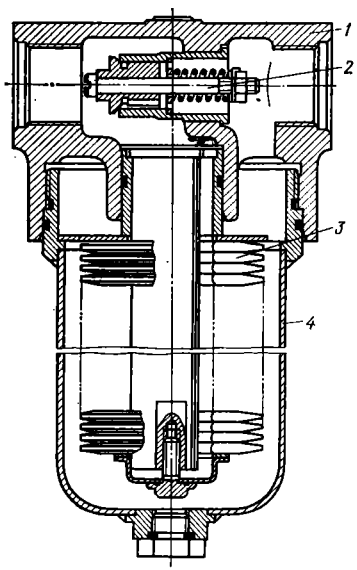


Fig. 5.7. Oil filter

1—cover; *2*—safety valve; *3*—filtering element; *4*—sediment bowl

Screen and leaf filters are intended to clean working fluid of impurities. The heavy motor grader is equipped with a screen filter arranged in the reservoir in the operating member return line (Fig. 5.1).

When filtering elements get clogged and their resistance to fluid flow increases to 0.2 MPa, the by-pass valve opens and fluid flows to the reservoir by-pass the filter.

A medium motor grader has a filter (Fig. 5.7) secured to the lateral tube of the frame. Working fluid from the system gets through a cover (*1*) to a sediment bowl (*4*) where large impurities settle down. Fine particles are entrapped by filtering elements (*3*).

The cover has a safety valve (*2*) which directs fluid by-pass the filtering element if pressure rises to 0.35 MPa.

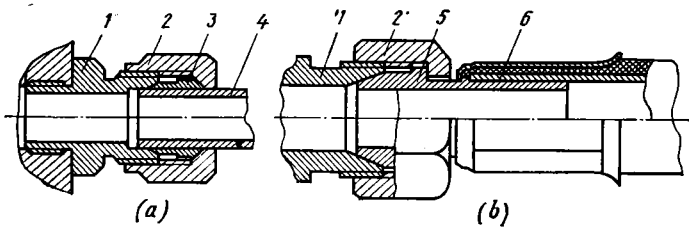


Fig. 5.8. Hydraulic pipeline joints

(*a*) rigid; (*b*) flexible; *1*—connection; *2*—union nut; *3*—penetrating ring; *4*—pipe; *5*—nipple; *6*—high-pressure hose

Table 5.3. Troubles and Remedies of Hydraulic System

Trouble	Cause	Remedy
When selecting LIFT position of hydraulic distributor, operating equipment does not lift or lifts very slowly	Excessive load	Decrease load. Add oil. Bleed hydraulic system
	Low oil level in reservoir. Air in hydraulic system	
	Maladjusted safety valve of distributor	Adjust pressure in system
	Defective pump	Replace pump
	Defective cup of hydraulic cylinder piston	Replace cup
Blade turning mechanism is inoperative	Defective hydromotor	Remove and check hydromotor
	Air in hydraulic system	Bleed hydraulic system
Excessive noise in operation	Maladjusted safety valve	Adjust safety valve
	Air in hydraulic system	Bleed hydraulic system
	Low oil level in reservoir	Add oil
	Defective pump	Replace or repair pump
System overheats	Air in system	Bleed hydraulic system
	Low oil level in reservoir	Add oil
	Worn-out pump	Replace pump
	Clogged filters	Wash filters

The filter safety valves are adjusted by changing the spring tension.

All the units of the hydraulic system are interconnected by pipes. Both rigid and flexible piping is used on motor graders. The rigid lines are made from steel drawn pipes interconnected by union nuts with penetrating rings (Fig. 5.8*a*). In the course of assembly, the penetrating ring (*3*) is free to move along a pipe (*4*) to adjust the required size between connections (*1*) at two ends of the pipe. After tightening the union nut (*2*) in the connection (1) the ring (*3*) is compacted around the pipe forming a groove in it and becomes stationary though the joint can be disassembled by means of the nuts *2*.

Flexible pipelines (Fig. 5.8*b*) are used to connect movable components of the hydraulic system, compensate for mounting errors and facilitate assembly. These are high-pressure hoses (*6*) consisting of an inner rubber layer, cotton and strong wire braids, intermediate and outer layers. Nipples (*5*) with union nuts (*2*) are attached to the hose ends to allow mating with the connection (*1*). The nut presses the spherical surface of the nipple to the connection taper forming a pressure-tight joint.

Troubles and remedies of the hydraulic system are listed in Table 5.3.

Chapter 6

STEERING SYSTEM

6.1. The Heavy Grader Steering System

A steering system (Fig. 6.1) comprises a steering gear (*5*) with hydraulic distributor, steering column (*7*), drag link (*2*) and tie-rod (*3*), and a power unit (*4*).

The operator's force applied to a steering wheel (*8*) is transmitted to the steering gear by universal joint shafts (*6*) and the force from the pitman arm of the gear (*5*) is imparted to the steering wheels by the drag link (*2*) and tie-rod (*3*). Fluid is fed to the power unit (booster) from a pump

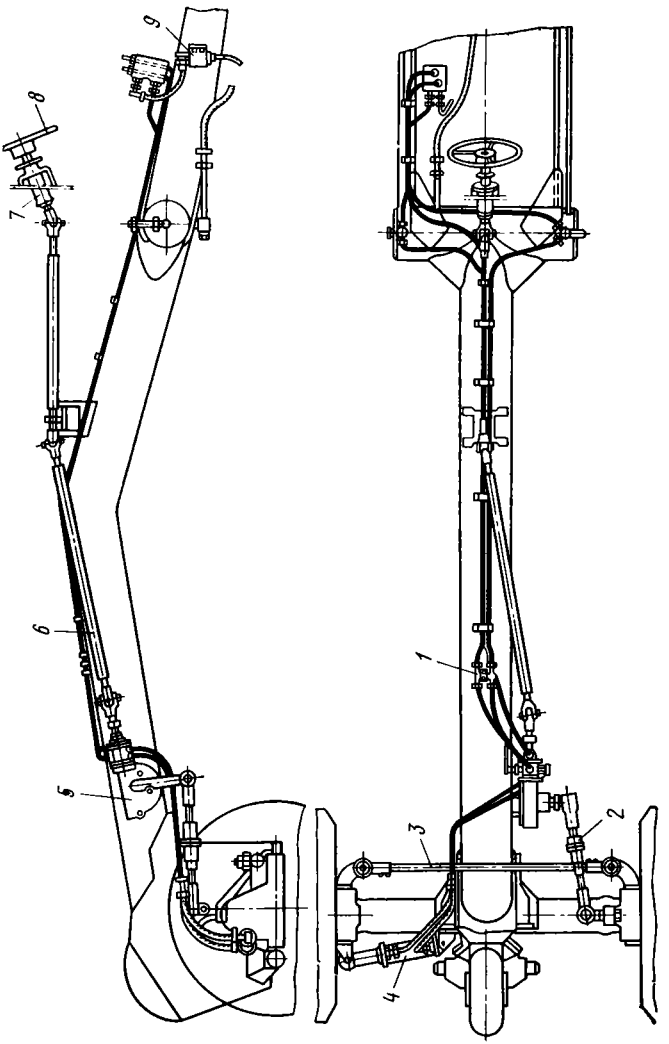


Fig. 6.1. The heavy grader steering system
1—safety valve; *2*—drag link; *3*—tie-rod; *4*—power unit; *5*—steering gear; *6*—universal joint shaft; *7*—steering column; *8*—steering wheel; *9*—pump

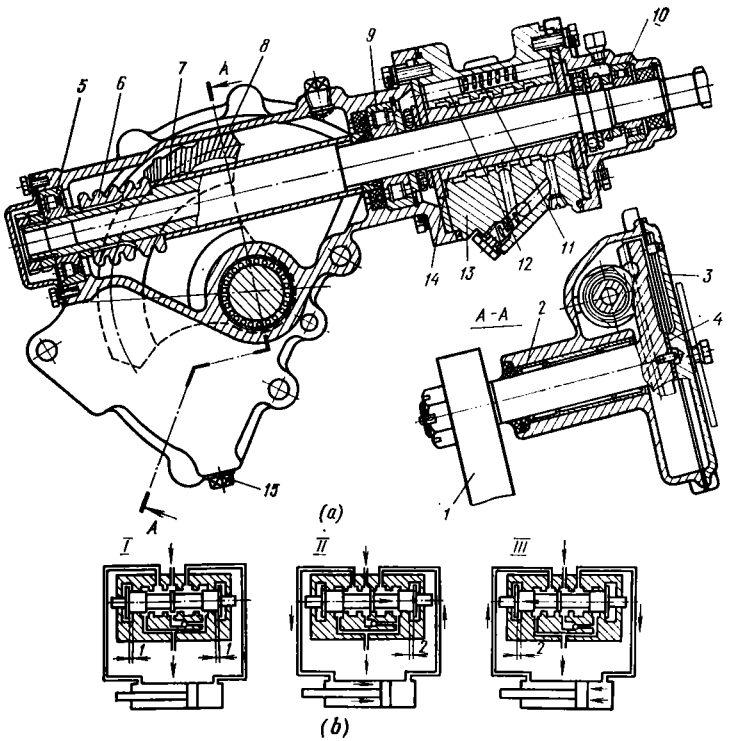


Fig. 6.2. Steering gear

(*a*) construction; (*b*) operation of hydraulic distributor; *1*—pitman arm; *2*, *5*, *9*, *10*—bearings; *3*—cover; *4*—thrust washer; *6*—worm; *7*—sector; *8*—housing; *11*—spring; *12*—plunger; *13*—body; *14*—slide valve; *15*—plug; *I-III*—operation stages

(*9*) mounted on the transmission intermediate gearbox. The system includes a safety valve *1* adjusted to a pressure of 6-7 MPa.

A steering gear (Fig. 6.2) consists of a worm pair and a hydraulic distributor. When the steering wheel is turned rightward or leftward, resistance of the steerable wheels prevents them and all linkage components including a sector (*7*) from turning and the worm (*6*) moves axially with a distributor slide valve (*14*) mounted on it. While moving the slide valve di-

rects oil from the pump to one of the hydraulic booster spaces and connects the other space to the return line causing displacement of the rods, hence turning of the steerable wheels (positions *II* and *III*).

The hydraulic booster rod keeps on moving till the steering wheel is stopped and the slide valve (*14*) is forced to the neutral position by reaction springs (*11*) acting upon a plunger (*12*).

This ensures a servo action of the steering system, i.e. the turn of the motor grader wheels depends on the turn of the steering wheel.

When the motor grader is moving straight ahead, the slide valve is in the neutral position (*I*) to bypass oil through the spool to the return line.

Oil for lubricating the gear is filled into a housing (*8*) through a filling plug and is drained through a plug (*15*). Oil lubricates the worm pair and bearings (*2*) and (*5*).

A steering column (Fig. 6.3a) is installed in the operator's cab. A steering wheel (*5*) with a shaft (*2*) rotates in bearings (*1*). Attached to the output end of the shaft is a universal joint yoke adapted to transmit the wheel torque to the steering gear. The steering column bearings (*1*) are lubricated through lubricators with the use of a grease gun.

A drag link (Fig. 6.3*b*) connects the pitman arm with the left-hand knuckle steering arm by adjustable ends with ball pins (*6*). The ball pin clearance is adjusted by tightening a nut (*7*).

Drag link springs (*9*) and (10) provide for changing its overall length to preclude damage to the steering gear during oscillations of the front axle.

A tie-rod (Fig. 6.3*c*) connects knuckle arms of both front wheels. The tie-rod is constructionally similar to the drag link but has not length-changing springs. The tie-rod interconnects the front wheels so that the right-hand wheel is turned in unison with the left-hand one and through the same angle. Besides, the rod adjustable ends are used to adjust toe-in of the front wheels which is necessary for stable movement of the motor grader.

The ball joints of the drag link and tie-rod are lubricated through grease fittings with the aid of grease guns.

A hydraulic booster of the steering system is a cylinder at-

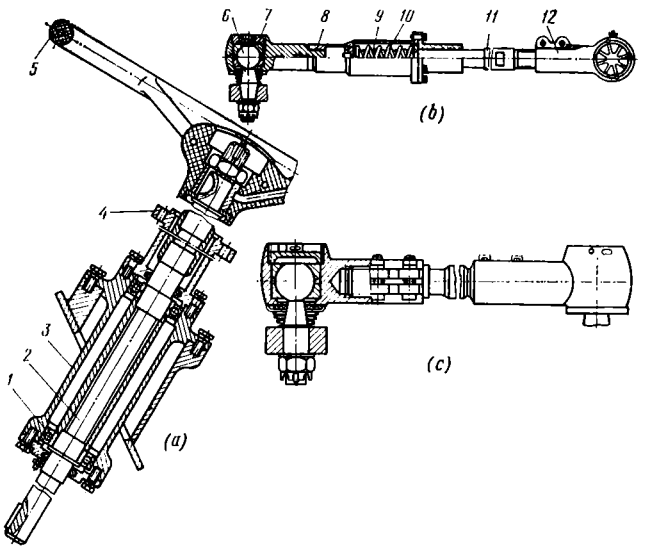


Fig. 6.3. Steering components

(*a*) steering column; (*b*) drag link; (c) tie-rod; *1*—bearing; *2*—shaft; *3*—body; *4*—bracket; *5*—steering wheel; *6*—ball pin; *7*—nut; *8*, *11*—rods; *9*, *10*—springs; *12*—right-hand end piece

tached to the knuckle and axle housing by ball joints similar to those used in steering linkage.

Apart from increasing force applied to the steering wheel by the operator, the booster damps reaction shocks when the steerable wheels encounter an obstacle.

Subject to adjustment in the steering system are: a wheel toe-in, clearances in ball joints of steering linkage and hydraulic booster, and a safety valve.

The valve is checked with the aid of a pressure gauge connected instead of the hose running from the rod space of the hydraulic cylinder. When the wheels are turned leftward the pressure should be up to 4 MPa, the full turn pressure should be 6-7 MPa.

Meshing of the gear with the sector of the steering gear is adjusted after complete assembly of the hydraulic distributor. When the sector is turned to either side from the neutral

position, the clearance increases. It should be 0-0.25 mm for the neutral position and from 0.25 to 0.5 mm for the extreme positions. The clearance is adjusted by installing thrust washers of appropriate thickness. The adjustment is checked by angular displacement of the pitman arm measured at a radius of 200 mm. The displacement should not exceed 0.06 mm for the neutral position and 0.7-1.2 mm for the extreme positions.

6.2. Steering System of Light and Medium Motor Graders

The steering system of light and medium motor graders also includes a hydraulic booster (Fig. 6.4). The force applied by the operator to the steering wheel is transmitted to the steering gear through universal joint shafts. When the steering wheel is turned, a worm (*8*) meshed with pins (*16*) of a crank (*9*) moves with the slide valve of a hydraulic distributor (*13*). As the slide valve is offset from the neutral position it admits oil to the space of a hydraulic cylinder (*3*) corresponding to the desired turn.

Fluid pressure makes a piston (*4*) displace turning the crank (*9*) and transmitting force from the latter to a shaft (*23*) of a pitman arm (*24*) thus turning the wheels. Oil from the other space of the cylinder flows to the return line. The crank (*9*) turns around the shaft (*23*) in unison with the turn of the steering wheel, hence with admission of oil through the slide valve to the respective space of the booster, and displaces the worm (*8*) in the opposite direction thus setting the slide valve neutral. This ensures a servo action of the steering system.

To protect the steering system against overloading, a ball safety valve (*12*) adjusted to a pressure of up to 8 MPa is built in the hydraulic distributor. When the pressure rises, oil from the delivery space overcomes resistance of the spring, which biases the ball to the seat, and a part of it flows to the return line.

The steering gear parts are lubricated from an oil bath. Oil is filled through a filling hole up to the check plug level.

Subject to adjustment in the hydraulic booster are pin

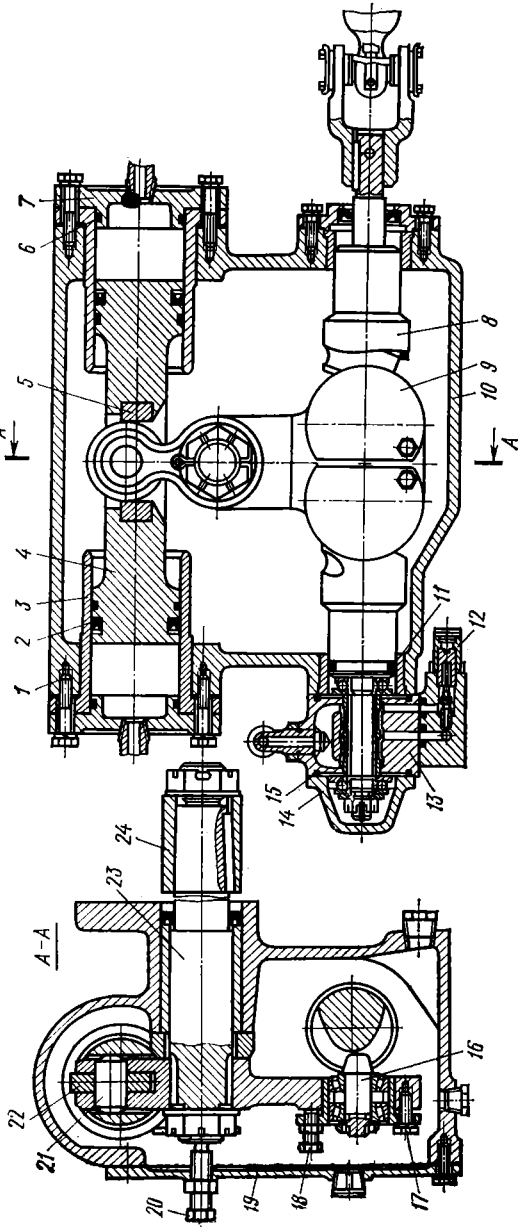


Fig. 6.4. Steering booster

1—steering gear; *2*—collar; *3*—hydraulic cylinder; *4*—piston; *5*—block; *6, 11*—rubber rings; *7*—hydraulic cylinder cover; *8*—worm; *9*—crank; *10*—body; *12*—safety valve; *13*—hydraulic distributor; *14*—distributor cover; *15*—seal; *16*—pin; *17, 18*—bolts; *19*—booster cover; *20*—set screw; *21*—axle; *22*—roller; *23*—shaft; *24*—pitman arm

tapered roller bearings, meshing of the worm with crank pins, worm thrust ball bearings and the safety valve.

The bearings of the pins (*16*) are adjusted after removing a cover (*19*) with the aid of nuts which are so tightened as to preclude longitudinal displacement of the pins. The pins should turn without jamming when a hand force is applied to them.

Meshing of the crank pins with the worm is adjusted with the grader wheels in the straight-ahead position and the pin clearance being taken up. A maintenance bar with a thrust screw (*20*) removed from the cover is installed in place of the cover (*19*). The screw is driven as far as it goes to take up all clearances. Next the bolts (*17*) are driven to the stop and backed for one turn.

Adjustment is checked with the engine running. The steering wheel should rotate freely. The steering wheel play

Table 6.1. Troubles and Remedies of Steering System

Trouble	Cause	Remedy
Hydraulic booster does not turn wheels or turning requires excessive steering wheel force	Maladjusted safety valve	Adjust valve
Foaming of oil in reservoir	Low oil level	Add oil
	Suction of air	Check and tighten pipeline joints
	Water in working fluid	Replace working fluid
Leakage of working fluid and lubricant from steering gear parts	Worn-out or damaged sealing rings and gaskets	Replace rings and gaskets
	Loosened cover attachment bolts	Tighten attachment bolts
Motor grader wheels lag behind considerably from steering wheel	Excessive clearances in joints	Check and adjust clearances
	Low efficiency of pump or suction of air	Replace pump. Eliminate suction of air

(free movement before the grader wheels start turning) should not exceed 27°.

After the check is over, adjust and lock the adjustment bolts (*18*), install the cover (*19*), and the screw (*20*). Drive the screw home, then back for $^1/_8$-$^1/_6$ turn and lock with the nut.

The worm thrust bearings are adjusted with the use of the nut after removing a cover (*14*). Tighten the nut and back it for $^1/_{12}$-$^1/_8$ turn till aligned with the nearest cotter pin hole on the worm shank.

The safety valve is adjusted by a screw. The grader wheels should be turned to the stop. Pressure is read against a pressure gauge installed in one of hydraulic cylinders (*3*).

Troubles and remedies of the steering system are listed in Table 6.1.

Chapter 7

ELECTRICAL EQUIPMENT

7.1. Circuitry

The motor graders have 12-V and 24-V DC equipment.

Figure 7.1 illustrates a layout of the 24-V electrical equipment on a motor grader.

The electrical units are interconnected by a single-wire circuit wherein the second wire is replaced by the metal parts of the machine (ground). The negative terminals of the power sources and one of the consumer poles are connected to the ground.

The motor grader electrical equipment is divided into the following main groups: power sources, power loads, switching gear and wires.

Power sources are storage batteries (*3*) and a generator (*22*) operating with a regulator (*15*).

Power loads include a starter (*19*) for starting the engine, electric motors (*20*), (*21*), (*23*) for the fuel booster pump, starting pre-heater fan and oil pump, respectively, instruments, turn signal lights (*1*), headlamps, marker lights, etc.

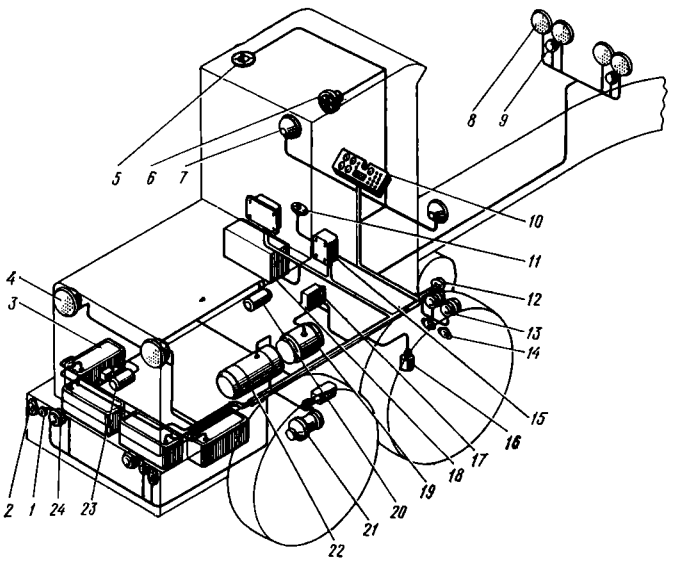


Fig. 7.1. Electrical equipment layout

1—tail (turn signal) light; *2*, *14*—reflectors; *3*—storage battery; *4*, *8*—rear and front headlamps; *5*—cab dome light; *6*—fan; *7*—cab headlamp; *9*—marker light; *10*—instrument panel; *11*—foot lighting switch; *12*—socket; *13*—horn; *15*—regulator; *16*—battery switch; *17*—starter relay; *18*—cab heater; *19*—starter; *20*—fuel booster pump electric motor; *21*—fan electric motor; *22*—generator; *23*—oil booster pump electric motor; *24*—stop light

Switching gear includes plug connectors for protecting the wire joints and facilitating removal, terminal boards and box for connecting the front and rear headlamps, an adapter outlet under the cab for connecting battery circuit wires of 70 mm^2 in cross section (battery switch), etc.

All externally-laid bundles are protected with oil- and moisture-resistant insulation tape and PVC sleeves.

The instruments are arranged on a panel (*10*) installed in the motor grader cab. The purpose of all units and instruments of the plate is indicated on the instruction plates.

Arranged behind the operator's seat near the regulator (*15*) is a switch (*16*) intended for connecting the storage batteries to and disconnecting them from the motor grader frame.

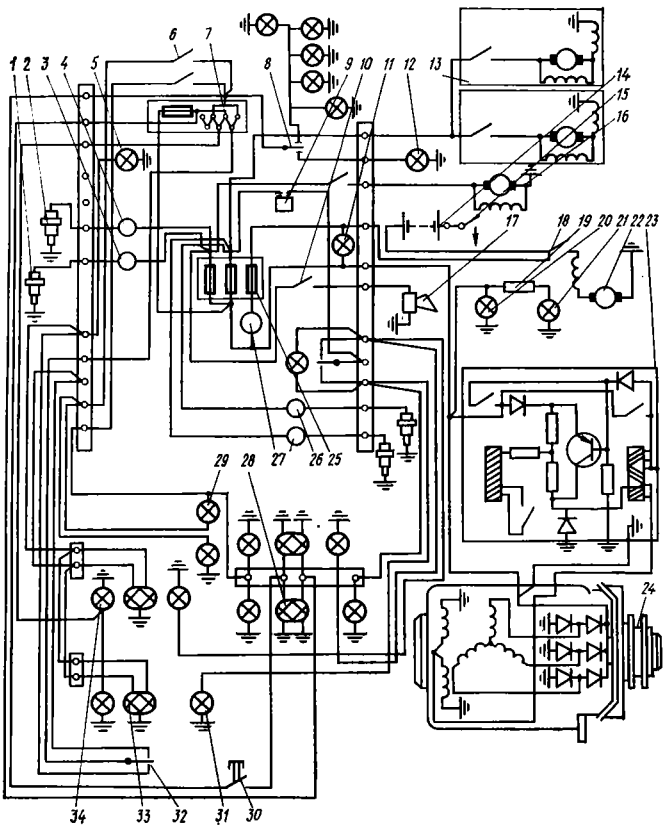


Fig. 7.2. Grader circuit diagram

1—torque converter oil pressure pickup; *2*—torque converter oil temperature pickup; *3*—torque converter oil pressure gauge; *4*—torque converter oil temperature gauge; *5*—upper beam indicator light; *6*—operating headlamp switch; *7, 8, 9, 32*—selector switches; *10*—horn switch; *11*—battery switch indicator light; *12*—dome light; *13*—windshield wiper; *14*—storage battery; *15*—battery switch; *16*—fan; *17*—electric horn; *18*—starter switch; *19*—socket; *20*—hood light; *21*—inspection lamp; *22*—starter; *23*—regulator; *24*—generator; *25*—fuse box; *26*—water temperature gauge; *27*—ammeter; *28*—tail light; *29, 33*—headlamps; *30*—STOP switch; *31*—turn light; *34*—marker light

The motor graders have several headlamps: two fixed headlamps (*4*) are arranged at the rear and have double-filament bulbs; two cab headlamps (*7*) with double-filament bulbs for

illuminating the grader blade operating area, which are pivotally mounted at the cab sides on brackets; front headlamps (*8*) and marker lights (*9*).

When the service brakes are applied, the stop light bulbs illuminate in the upper compartment of the tail lights (*24*).

A horn (*13*) is arranged on the front external wall of the cab near a socket (*12*) used to connect an inspection lamp.

The light and medium motor graders equipped with a starting engine require less power for the starter and loads and run on 12 V. A 12-V circuit diagram of a medium motor grader is shown in Fig. 7.2.

7.2. Construction of Main Components

Storage batteries store electricity or are charged from a generator and supply it to the loads (are discharged) when the generator is not running. The motor graders use 12-V batteries which are connected in pairs for a 24-V circuit.

Each battery includes six 2-V cells connected in series. The positive plates of lead-acid batteries are made from lead peroxide and the negative plates from spongy lead.

Electrolyte used with the lead-acid batteries is a solution of sulphuric acid with a density of 1.83-1.84 diluted with distilled water. The battery comprises several positive and negative plates, the like plates being connected in parallel. The plates are arranged close to each other so that separators

Table 7.1. Specific Gravity of Electrolyte

Climatic zone	Ambient temperature, °C	Specific gravity of electrolyte at	
		15°C	30°C
Southern	Down to —20	1.250	1.240
Central	Down to —30	1.280	1.270
Northern	Down to —40	1.290	1.280
Continental			
winter	Below —40	1.310	1.300
summer		1.270	1.260

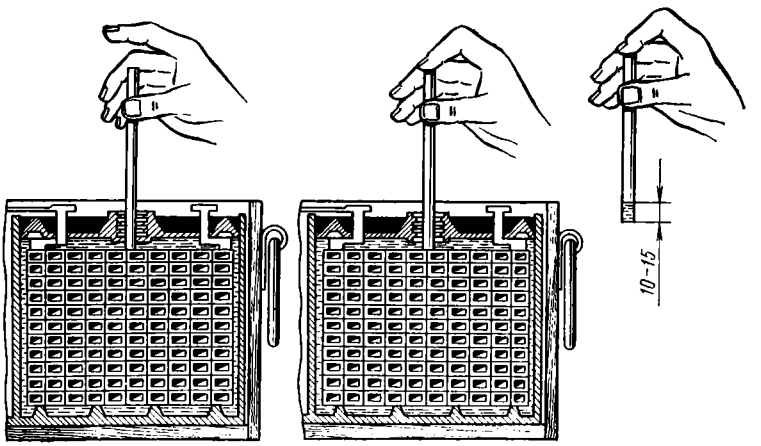


Fig. 7.3. Checking electrolyte level in storage battery

made of insulation material are disposed between them to preclude shorts. The cells are integrated in a hard rubber container.

Prior to activating the battery, remove rubber plugs from the filling holes and pour electrolyte. Specific gravity of electrolyte to be filled in the battery depends on the season, climatic conditions and should be as indicated in Table 7.1.

The electrolyte level should be 10-15 mm above the protective shield (Fig. 7.3), the total amount of electrolyte to be filled is 7.8 l. Electrolyte temperature should not exceed 25°C. Wait for 2 to 3 h after pouring electrolyte and hook up the battery for charging. Electrolyte temperature in the battery should not exceed 35°C. Keep on charging with current of 11-12 A for at least 5 h till the electrolyte specific gravity and the battery voltage remain stable during 2 h at intensive gassing. At the end of the 5-h charging cycle, the electrolyte specific gravity corrected to 15°C should not differ from that of as-poured electrolyte (also corrected to 15°C) by more than 0.01. If the required specific gravity is not reached, decrease the current to 8-7 A and keep on charging to a constant specific gravity measuring it thrice during 2 h. If the electrolyte temperature rises above 45°C during charging, decrease

Table 7.2. Electrolyte Specific Gravity vs Temperature

Electrolyte specific gravity at 15°C	Electrolyte specific gravity at temperature, °C			
	30	40	50	60
1.310	1.305	1.295	1.290	1.280
1.290	1.280	1.278	1.265	1.258
1.270	1.265	1.255	1.250	1,240
1.250	1.245	1.235	1.230	1.220
1.230	1.225	1.215	1.210	1.200

the charging current to 4-5 A accordingly increasing the charging period. If the trouble persists, discontinue charging and cool the electrolyte to 35°C.

The electrolyte specific gravity in view of temperature correction (Table 7.2) measured after charging may turn out somewhat higher than that of as-poured electrolyte. If this is the case, add distilled water and continue charging for 30 min more to fully mix electrolyte. Then cut out the battery, wait for at least 30 min and measure the electrolyte level in all the cells. If it is below the specified limit, add electrolyte of the same specific gravity as used for initial filling. If the lever is too high, remove the excess by a rubber bulb.

The electrolyte specific gravity is measured with the aid of a special device called hydrometer (Fig. 7.4).

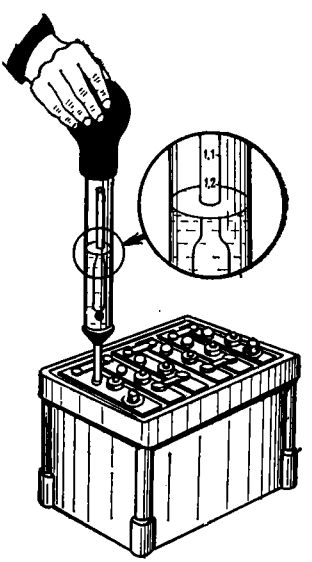


Fig. 7.4. Measuring electrolyte specific gravity with hydrometer

A hydrometer is a glass tube with a rubber bulb at one end, and a float with a scale. The hydrometer is immersed into

the filling hole of a battery and electrolyte is sucked into the tube by means of a bulb. The float will rise to a certain level corresponding to the electrolyte specific gravity marked on the scale.

Troubles and remedies of storage batteries are listed in Table 7.3.

Table 7.3. Troubles and Remedies of Storage Batteries

Trouble	Cause	Remedy
Rapid discharge	No charging from generator	Check charging current
	Current leakage along battery surface	Wipe battery surface with 10% solution of ammonium hydroxide
	Contaminated electrolyte	Forward battery for charging
	Plate sulphation	Forward battery for repair
When cutting in starter, voltammeter reads voltage less than 17 V. Starter armature rotates slowly	Oxidized posts or loosened attachment of leads	Clean posts and lead terminals. Reliably connect terminals to post and coat them with petroleum jelly
	Discharged battery	Forward battery for charging
Electrolyte rapidly vanishes from one or several cells, wet stains appear	Cracked container	Forward battery for repair
When tested with cell tester one or several cells display voltage close or equal to zero	Short-circuited battery	Forward battery for repair

A generator is an AC fully enclosed electric machine intended to feed loads and charge storage batteries.

A heavy motor grader is equipped with 3-kW, 100-A generator with a rated voltage of 28 V automatically adjusted to the accuracy of $\pm$ 1.5 V by a regulator. The generator is connected to the circuit automatically by the regulator de-

pending on the engine rating. The regulator maintains constant voltage across the generator terminals and precludes overloading.

The generator requires no in-service adjustments except V-belt tension. When a force of 40 N is applied to the middle of the V-belt, the sag should be 10-15 mm. The regulator is adjusted and checked by electricians. Troubles and remedies of the generator and regulator are listed in Table 7.4.

Table 7.4. Troubles and Remedies of Generator and Regulator

Trouble	Cause	Remedy
Generator puts out low or no charging current	Damaged wire between generator, regulator and storage batteries	Eliminate defects
	Soiled or oiled commutator	Wipe commutator surface with soft cloth slightly moistened in alcohol. If commutator cannot be cleaned this way, burnish it with emery cloth at slow rotational speed and blow with compressed air
	Worn-out brushes	Replace brushes and seat them to commutator
	Open or short circuit in armature or field winding	Forward generator for repair
	Defective regulator	Forward regulator for repair
Excessive charging current	Short circuit of wires connecting generator to regulator	Eliminate defect
	Defective regulator	Forward regulator for repair
Fluctuating charging current	Soiled or oiled commutator	Clean commutator
	Insufficient brush pressure	Adjust pressure
	Defective regulator	Forward regulator for repair

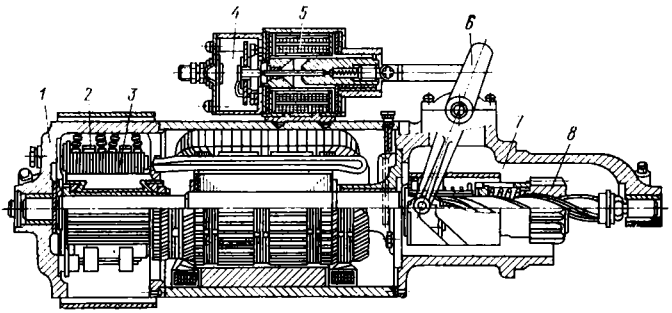


Fig. 7.5. Starter

1—electric motor; *2*—brush; *3*—commutator; *4*—solenoid relay; *5*—solenoid coil; *6*—shift lever; *7*—drive; *8*—drive pinion

A starter (Fig. 7.5) is a DC motor intended for short-time operation from storage batteries. It comprises a motor (*1*), a drive (*7*) and a solenoid relay (*4*). A drive pinion (*8*) of

Table 7.5. Troubles and Remedies of Starter

Trouble	Cause	Remedy
Starter is inoperative	Open circuit between starter and battery,	Check connection of wires and solenoid relay
	Defective solenoid relay	
	Low brush pressure	Replace brushes and seat them to commutator
	Burnt-out contacts in solenoid relay	Burnish contacts
	Defective cut-in button	Repair button
Starter does not rotate engine crankshaft or rotates it very slowly	Discharged or defective batteries	Forward batteries for repair
	Open circuit between starter and battery	Check connections
	Low brush pressure	Adjust brush pressure
	Worn-out or burnt commutator	Forward for repair
Starter pinion does not mesh with flywheel rim with starter operating normally	Mutilated or broken teeth of drive pinion	Dress teeth or replace drive pinion
	Starter displaced from its location	Reinstall starter to its location and tighten clamps

the starter is brought into meshing with the flywheel rim by a solenoid (*5*) mounted on the starter housing with the aid of a shift lever (*6*) and is unmeshed automatically after the engine is started.

The starter requires no in-service adjustments. Troubles and remedies of the starter are listed in Table 7.5.

Chapter 8

BLADE AUTOMATIC CONTROL SYSTEM

8.1. Design

The motor graders are often used for grading operations. To ensure accurate profiling, the operator has to decrease the cut, hence the amount of soil removed during one pass. Besides, he often slows down the grader otherwise there is not enough time for controlling the blade to obtain the required profile and smoothness. This decreases the productivity of grading operations and causes the operator's fatigue. Therefore automation of operating equipment control is of great importance for performing accurate grading.

The motor graders are equipped with blade automatic control system Profile-10 and Profile-20.

The Profile-10 system is intended to automatically adjust the blade slope angle irrespective of the roadbed transverse profile and is used for finishing or profiling the surface. The system provides for operating the machine both with manual control of the blade and with automatic profiling.

The Profile-10 system (Fig. 8.1*a*) includes an angle transducer (*2*), a control unit (*4*), a hydraulic distributor (*6*) with electrohydraulic control which is connected to a hydraulic cylinder (*3*).

The automatic circuitry is fed from machine storage batteries (*5*). Oil is fed to the hydraulic distributor (*6*) from the main hydraulic system of the motor grader.

The angle transducer (Fig. 8.2) is a device intended to convert angular position of the body relative to the gravity vertical to an electric signal. A sensing element is a rocker (*1*) suspended from a pivot (*2*) mounted on ball bearings (*3*).

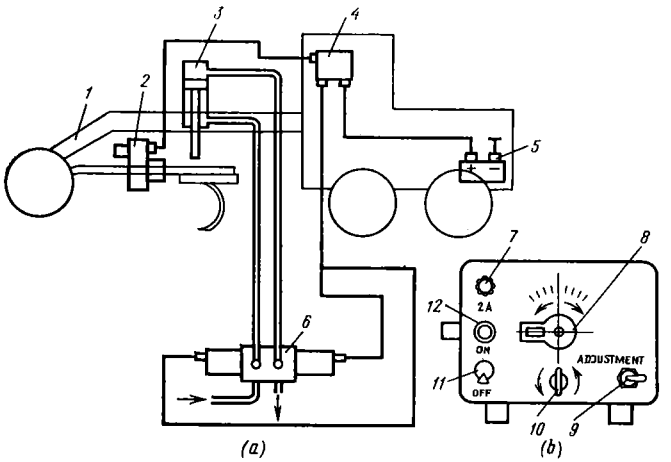


Fig. 8.1. Profile-10 system

(*a*) circuit diagram; (*b*) control unit; *1*—motor grader; *2*—angle transducer; *3*—blade right-hand lifting cylinder; *4*—control unit; *5*—storage battery; *6*—hydraulic distributor; *7*—fuse; *8*—blade slope angle setter; *9*—adjustment toggle switch; *10*—penetration knob; *11*—switch; *12*—indicator lamp

Attached to the pivot (*2*) is a shield (*4*) interacting with transducer coils (*5*).

As the body turns relative to the rocker, the relative change between the positions of the shield and coils causes a proportional change in the output signal.

The angle transducer is arranged on the grader draft frame at the right-hand hydraulic cylinder side so that the rocker oscillation axis coincides with the axis of turn of the draft frame relative to the spherical bearing. When the transducer deviates from the horizontal position, an indicator lamp (*1*) comes on. The transducer is arranged in a holder which permits turning it in the vertical plane for setting to the desired angle.

A control unit (Fig. 8.1*b*) is intended to preset the blade grade and transmit signals from the transducer to the hydraulic distributor solenoids. The unit cover mounts toggle switches for cutting in and knobs for adjusting the system. The control unit is arranged in the operator's cab so that its face panel is within easy reach of and readily seen by the operator.

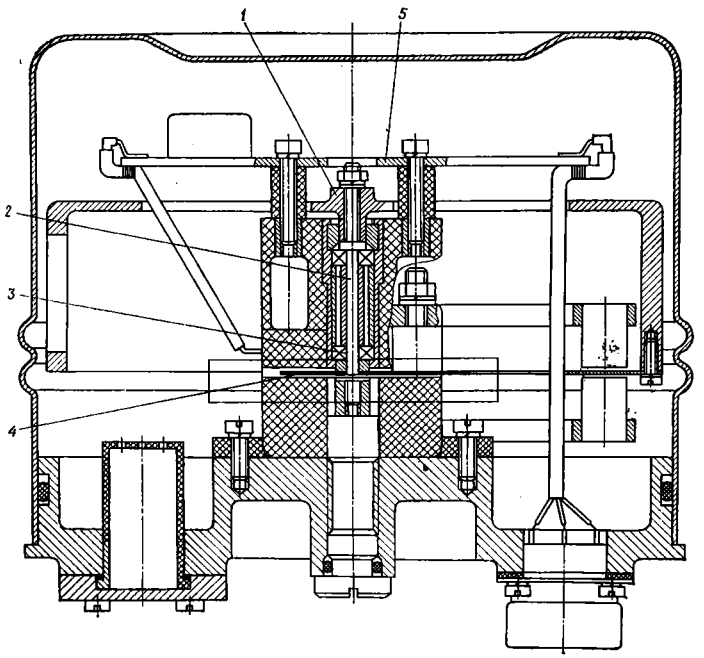


Fig. 8.2. Angle transducer
1—rocker; *2*—pivot; *3*—bearing; *4*—shield; *5*—transducer

A hydraulic distributor with electrohydraulic control (Fig. 8.3) consists of a master hydraulic distributor (*5*) and a control distributor (*4*).

The control distributor is actuated by solenoids (*1*) energized from the electrical system. The solenoids can be cut in manually by buttons (*3*). When energized, the solenoid shifts a slide valve (*2*) and directs working fluid through a respective passage to a slide valve (*6*). Fluid pressure in the control line makes the slide valve (*6*) move thus admitting oil to the required space of the grader blade hydraulic cylinder.

The hydraulic distributor is mounted on the motor grader frame.

The Profile-20 system likewise the Profile-10 is intended

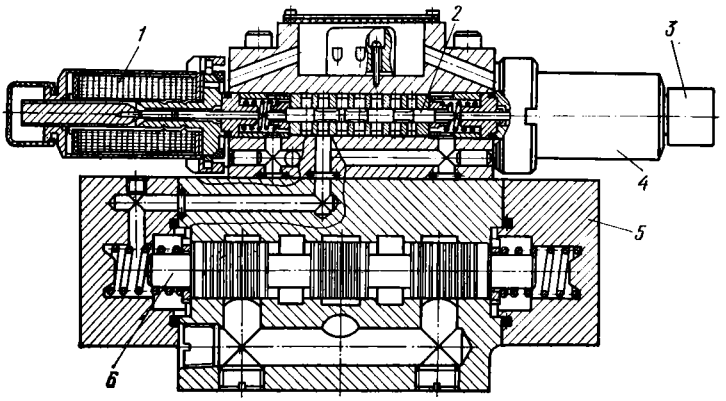


Fig. 8.3. Hydraulic distributor

1—solenoid; *2*, *6*—slide valves; *3*—button; *4*—control distributor; *5*—master distributor

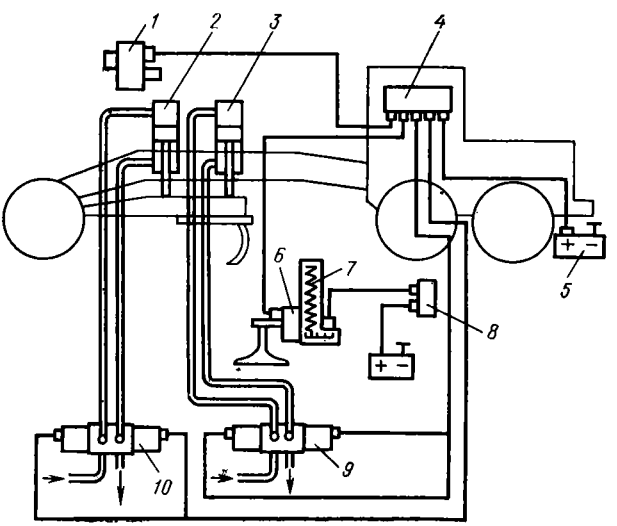


Fig. 8.4. Profile-20 system

1—angle transducer; *2*, *3*—blade lifting cylinders; *4*—control panel; *5*—storage battery; *6*—longitudinal profile transducer; *7*—lifting device; *8*—lifting device control unit; *9*, *10*—hydraulic distributors

to ensure a constant position of the blade in the lateral plane and to automatically control its height. The Profile-20 system offers the following modes: manual control, maintenance of preset longitudinal profile, maintenance of preset lateral profile, maintenance of both longitudinal and lateral profiles.

The Profile-20 system (Fig. 8.4) is distinguished basically in the use of a longitudinal profile transducer (*6*) with a lifting device (*7*). This is a feeler unit responding to the feeler turn deflecting from the preset position.

Troubles and remedies of automatic system are listed in Table 8.1.

Table 8.1. Troubles and Remedies of Automatic System

Trouble	Cause	Remedy
When cutting in power toggle switch indicator lamp does not illuminate on unit	Blown fuse	Replace fuse
	Burnt lamp	Replace lamp
	Defective control unit	Repair control unit
When cutting in power and adjustment toggle switches, indicator lamp on transducer does not illuminate	Burnt indicator lamp	Replace
	Defective transducer	Repair
	Incorrect setting of transducer	Check setting
	Defective control unit	Repair control unit
With transducers in preset position, blade does not fulfil commands	Incorrect position of transducer	Check transducer setting
	Incorrect coupling of connectors	Check coupling, recouple plug connectors between control unit and solenoids
	Hydraulic distributor does not operate	Check circuitry. Clean hydraulic distributor

8.2. Operating Principle

The Profile-10 automatic blade control system operates on the following principle.

When the motor grader deviates from the preset position in the lateral plane while moving, the blade with the draft

frame and the angle transducer body also deviate, while the rocker turns on its pivot to remain in the original position. The changed output signal of the transducer is fed to the control unit which supplies a command to the solenoid of the hydraulic distributor. The solenoid shifts the slide valve from the LOCKED position to the extreme one thus admitting oil to the respective space of the blade lift cylinder.

The blade with the draft frame and transducer body change their slope angle till the initial position of the transducer body relative to its rocker is restored. As such a position is attained, electric signal to the control unit ceases, hence no voltage is applied to the distributor solenoid and the cylinder stops the blade at the desired slope angle.

Thus, at any deviation of the blade from the preset position the angle transducer signal is as it were compared with the preset signal of the control unit. The mismatch signal cuts in the solenoid of the hydraulic distributor. The cylinder displaces the blade till the mismatch is eliminated.

Preparation of the automatic system for work is confined substantially to setting the angle transducer and blade initial position.

When performing profiling or finishing operations with insufficient slope angle of the blade, the blade cutting edge is set to the horizontal position with a plan angle of 90°. Then the angle transducer is so set that the indicator lamp (*1*) is dead. Such a position of the transducer corresponds to the horizontal position of the blade.

When working on slopes up to 30°, the blade is set to the required angle and the transducer is displaced till the lamp goes out.

The angle transducer is adjusted after cutting in the system for tuning (Fig. 8.1). A toggle switch (*9*) and switch (*11*) are cut in and the pointer of a setter (*8*) is zeroed. Cut-in of the system is indicated by a flash of lamp (*12*).

The automatic system is cut in for operation by the switch (*11*). The tuning toggle switch (*9*) should be cut out.

The required slope angle of the blade is set by turning the knob of the setter (*8*). Two scales and pointers of the setter indicate lifting and lowering of the blade right-hand side which are automatically controlled.

The amount of cut is adjusted manually by displacing the

left-hand side of the blade. The right-hand side is displaced in unison with it by the automatic system which maintains the required slope angle.

During movement of the motor grader equipped with the Profile-20 system, the feeler of a transducer (*6*) (Fig. 8.4) slips along a reference line such as a wire, rope, curbstone or pre-levelled surface to follow the preset profile.

If the feeler deviates beyond the dead zone, the transducer supplies a signal to the amplifier in the control unit. The hydraulic distributor solenoid supply circuit is closed, the distributor makes the cylinder displace the blade in the vertical direction. The displacement ceases when the feeler slipping over the reference line returns to the dead zone. To ensure contact between the feeler and the reference line, the transducer is adjusted in height with the aid of a screw lifting device.

The blade automatic control mode is primarily used for such operations as soil moving and spreading, profile finishing, etc. Rough operations which require a considerable tractive effort, such as cutting, should be performed in the manual mode.

To increase the efficiency of using the motor graders with automatic blade control it is recommended to employ them for work which requires accurate maintenance of slope angle, volume of work sufficient for continuous use of automatics, organize the grader passes so that the wheels of the non-automated side of the machine run on a smoother surface, preprofile the road along the center line whenever possible (the amount of cut should not exceed 7 cm).

Part Two

Operation Planning and Practices

Chapter 9

FUNDAMENTALS OF ROAD WORK

9.1. Automobile Road Structure

Automobile roads are the roads built according to the established technical rules and requirements for ensuring continuous, convenient and safe movement of transport vehicles.

Automobile roads are constructed within the assigned area strips which also include territory along the road and the maintenance structures.

The principal elements of an automobile road (Fig. 9.1) are a roadbed (*6*) and a carriage (*5*).

Roadbed is a soil formation shaped to receive the carriageway. The roadbed includes drains, and reinforcement and protection structures (shoulders (*7*), side ditches (*4*)).

Road shoulder is a side portion of the roadbed between its edge (*8*) and the edge of the carriage intended to form a carriageway support during construction of the road, protect the covering against breakage, and allow siding and parking of motor vehicles when the carriageway width is insufficient. During road maintenance the shoulders are used for

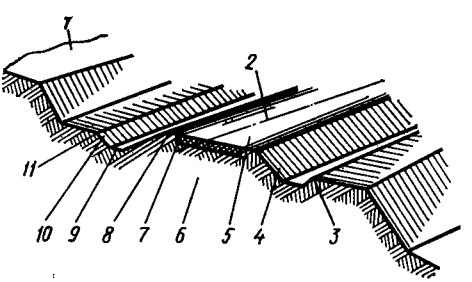


Fig. 9.1. Elements of automobile road structure

1–ground surface; *2*–roadbed center line; *3*, *8*, *11*–side ditch edges; *4*–side ditch; *5*–carriageway; *6*–roadbed; *7*–shoulder; *9*–side ditch bottom; *10*–side ditch slope

temporal storing of materials. Besides, the shoulders offer a reserve for widening the carriageway.

Side ditches are intended to drain water from water-bearing layers. They also collect water flowing from the carriageway surface. The side ditches direct water to artificial structures or onto the low ground. The ditch side walls are called slopes (*10*).

The side ditches are triangular or flat-bottom in cross section. The lines of intersection between the roadbed and the ditch slopes are called *edges* (*8*), (*11*). The edges (*3*), (*11*) of the side ditches determine the total width of the roadbed. The ratio of the slope height to its depth, i.e. a horizontal distance between the edge and a bottom (*9*) corresponds to the slope steepness. With a slop height assumed to be unity, the slope steepness is 1 to 3 at an embankment of below 1 m and 1 to 1.5 at an embankment of above 1 m.

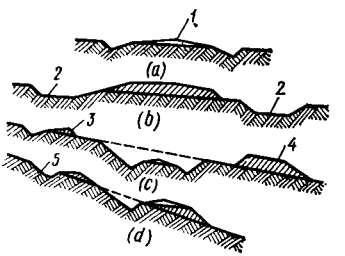


Fig. 9.2. Lateral cross sections of roadbed

(*a*) zero elevation of embankment; (*b*) embankment filled from borrow pits; (*c*) cutting; (*d*) cut-and-fill; *1*—embankment; *2*—borrow pit; *3*—banquette; *4*—bank; *5*—catch-water drain

The cross section of a roadbed (Fig. 9.2) is formed of fills and cuts. The need for these is determined by the terrain where the road is to be constructed. If the road is to pass above the ground level, soil is filled, i.e. an embankment is built (Fig. 9.2*b*). If the ground level is above the road elevation, a layer of soil is removed to make a cut (Fig. 9.2*c*). The cut includes gulleys, gutters, and water drains. In case of sidelong slopes, one part of the road can be in the cutting and the other on the embankment. Such a structure is known to have a cut-and-fill section (Fig. 64*d*).

If the amount of soil removed from side ditches is insufficient for building up the embankment, borrow pits (*2*) are used.

Soil removed from cuttings is transferred to the embankment, but if it is in surplus, banks of geometrically regular shape are formed. These are termed spoil banks. The spoil

banks (*4*) are usually arranged at the edges of the cutting downhill side.

To protect the roadbed against uphill water, catch-water drains (*5*) are made.

The longitudinal profile of a road represents its longitudinal cross section with all rises and falls and is characterized by gradient expressed in percent. The height difference between two points of the longitudinal profile is called *elevation*, while the horizontal distance between these points is called *contour interval*. The *road gradient* is obtained by dividing the elevation by the contour interval in metres.

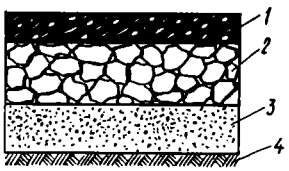


Fig. 9.3. Pavement

1—surface; *2*—foundation; *3*—foundation additional layer; *4*—roadbed soil

If the height difference between the points is 10 m, and the distance between them is 100 m, the gradient is

$$i = 10/100 = 0.1 \text{ or } 10\%$$

The permissible gradient depends on the road type. Thus an earth road may have a gradient of up to 9%, while in case of a concrete road, its value should not exceed 4%.

Carriageway is a strong and tight surface devoted to the use of vehicles and is arranged symmetrically to center line (*2*) (Fig. 9.1) of the roadbed.

The upper dense surface of the carriageway is made of a pavement (Fig. 9.3) comprising several layers.

Surface (*1*) is a top layer which takes up the load of vehicle wheels and is exposed to the elements. It can comprise a wearing coat subject to renewal as required and a base course which determines the type of surface.

Foundation (*2*) is a part of the pavement which spreads the load over the subsoil (formation). The foundation also comprises several layers: a strong top layer and an additional layer transmitting loads to the subsoil and doubling as frost-protecting, draining and smoothing layer (it is also called frost blanket).

According to the surface material and strength, the pavements are divided into the following types:

light-duty — earth surface reinforced with various local materials;

medium-duty—broken stone surface treated with liquid binders, pebble surface;

improved medium-duty—macadam and gravel roads treated with organic binders, earth bound with viscous bitumens;

heavy-duty—cement-concrete and asphaltic concrete surfaces.

The pavement is laid over a graded and compacted subsoil surface wherein a trench may be cut if required by the surface type and material (Fig. 9.4).

The flat-bottom section (Fig. 9.4*a*) is used on light-duty earth roads. The material reinforced by various additions is spread over the entire roadbed width.

Medium-duty surfaces of gravel can be of a flat-bottom or a half-trench section (Fig. 9.4*b*). The half-trench section saves material by decreasing the shoulder layer thickness.

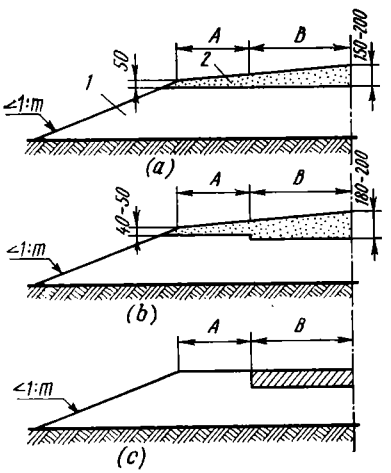


Fig. 9.4. Pavement profile

(*a*) flat-bottom; (*b*) half-trench; (*c* trench; *A*—shoulder; *B*—carriageway; *m*—slope base; *1*—roadbed; *2*—pavement

In case of a trench section (Fig. 9.4*c*), material, say broken stones, is laid only within the carriageway width.

Motor roads are classed as follows:

— national highways intended for long motor haulage between major cities, industrial and cultural centers;

— roads interconnecting administrative, economic and cultural centers, as well as areas and regions, and major cities;

— area and regional roads;

— local roads linking settlements, villages, etc.

According to the type, traffic capacity and design speed, the motor roads fall into five categories with the most impor-

tant norms and characteristics specified for each of them (Table 9.1).

Table 9.1. Motor Road Characteristics

Characteristic	Road category				
	I	II	III	IV	V
Average annual traffic load in both directions	Over 7000	3000-7000	1000-3000	200-1000	Below 200
Design speed, km/h	80-150	60-120	50-100	40-80	30-60
Number of lines	4 and more	2	2	2	1
Carriageway width, m	15 and more	7.5	7	6	4.5
Roadbed width, m	27.5 and more	15	12	10	8
Maximum gradient, %	3-6	4-7	5-8	6-9	7-10

9.2. Soil and Road-Building Materials

Soil is a material for building the roadbed of motor roads. The earth surface layer or turf is a poor building material and a few of it is used for constructing the roadbed. Main building material is subsoil worked by excavating and earth-moving machines.

Kinds of soil. As regards their composition, soils are classed into sandy, silty, loamy, clay, loess, peat and rock.

The soil properties depend mainly on grain size in millimetres and on granulometric composition, i.e. the ratio of grains of different sizes.

The basic properties of soils are coherence, water permeability, water absorption, loosening, natural angle of repose and compaction. These properties to a considerable extent dictate the strength of a roadbed.

Soil coherence is characterized by the value of force required to separate cohered particles. Rocks and clay soils offer the greatest coherence.

Soil water absorption is its ability to absorb water without passing it through. This property is found in clay. Soils containing up to 5% of water relate to dry, up to 30% to wet and over 30% to water-logged kinds.

Water permeability is the ability of soil, say sands, to pass water.

Loosening is the soil ability to increase its volume in working. The ratio between the volume of loosened and compacted volumes is called the *loosening ratio.* Clay and loam display maximum loosening (26-32%).

If loosened soil is banked, its slopes will be arranged at a definite angle characteristic for this particular soil and its moisture content. This angle is called the *angle of repose.* For instance, the angle of repose of sandy soils is from 15 to 30°, of loams from 25 to 50°, lesser values corresponding to wet soils.

Compaction of soils characterizes their ability to be tightly compacted in banks.

Density of soils is defined as the weight per unit volume of a substance, e.g. 1 m^3 of compacted soil, and is measured in kg/m^3.

Sandy and loamy soils are good materials for constructing a roadbed. Clay can hardly be used for the purpose. When moved by machines clay soils intensively clot, separate clots are difficult to compact which leads to voids in the embankment.

As regards their susceptibility to working by motor graders, all soils fall into three groups. The greater is the soil group number, the higher is the required grader effort (Table 9.2).

The soil group is an important factor in the motor grader productivity, therefore it should be taken into account in planning and organizing the earth-moving operations.

Apart from earth-moving for constructing a roadbed, the motor graders are used for working with various road-building materials used for mixing with soils. Mixtures of soils with organic and mineral materials increase strength of the carriageway surface and its resistance to destruction by the motor vehicle wheels and can constitute a foundation for an improved pavement.

Table 9.2. Groups of Soils

Soil	Group
Pebble and gravel, up to 80 mm in size	II
Clays	
fat, soft or loose without gravel	II-III
heavy compact clay	III
Vegetable layer without roots and cobblestones	I
Loess	
natural humidity with gravel or pebble	I
dry with admixtures	II
Sand	
natural humidity without admixtures	II
dry loose	III
Loam	
sandy and clay	I
with gravel admixture	II
Sand loam	II
Alkali and saline soils	
soft	I
hard	III
Peat without or with roots, up to 30 mm	I
Chernozem and chestnut soils	
natural humidity	I
hard	III

Building materials. Gravel, ballast and sand are the most common mineral building materials.

Gravel is crushed rock consisting of rounded grains from 2 to 40 mm in size with admixtures of sand, dust and clay. Gravel is used to build gravel pavements or foundations for improved pavements.

Ballast is crushed rock consisting of angular grains from 5 to 75 mm in size.

Sand is a product of destruction of rock. Sand grain size is from 0.05 to 2 mm, silty particle content is up to 15%, clay content up to 3%.

Ballast and sand are used as foundations for improved pavements.

Soils are consolidated by both organic (bitumen, tar) and inorganic *binding materials* (cement and lime). Particles of bitumen which is obtained from oil refinery waste or of tar

are mixed in the form of a water emulsion with the soil of the carriageway.

Soils consolidated by cement are called cement-soil mixtures. Such a mixture hardens in 1 to 2 h under the action of water and compaction to form a sturdy surface.

Chapter 10

MOTOR GRADER OPERATION HINTS

10.1. Roadwork Operations and the Use of Motor Graders

Motor graders are widely used in land reclamation, construction of railways, hydraulic developments, airfields, etc. Their main use, however, is in motor roads construction and maintenance. The motor graders perform profiling and grading of the roadbed, make excavations in the roadbed for the pavement base course, build up embankments and banks up to 1.2-m high, cut side ditches up to 0.8-m deep, cut and

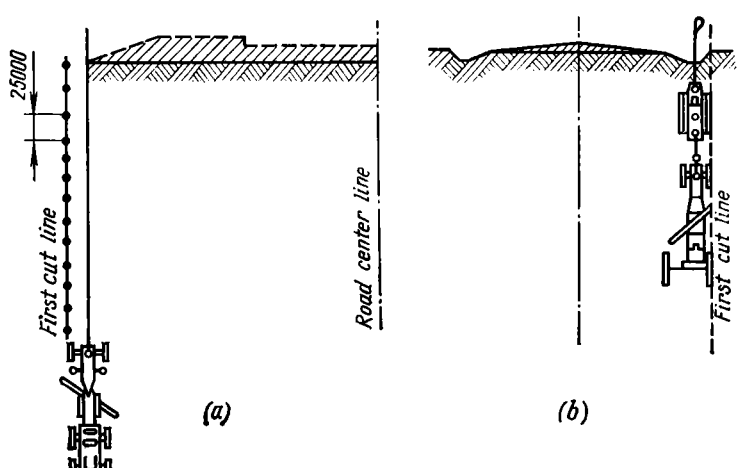


Fig. 10.1. Making first cut
(*a*) using pegs; (*b*) using poles

profile slopes, move and spread gravel and broken stone over the carriageway, construct hard top surfaces by mixing in situ inert materials with binders, arrange and maintain earth-moving roads for scrapers and dump trucks.

Maintenance operations performed by motor graders include cleaning of side ditches, gutters, and drains, snow ploughing and ice crushing. High grading productivity of motor graders provides for using them in levelling vast areas. All this work is carried out mainly with the aid of a grader blade and involves a number of basic operations.

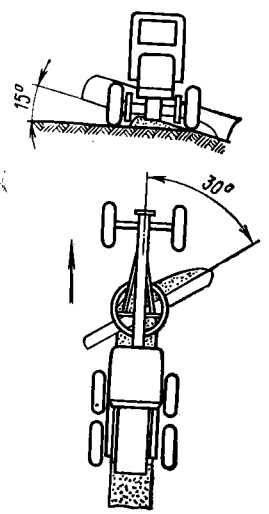


Fig. 10.2. Cutting operation

Cutting is the first operation with all kinds of earthwork. The most vital stage of this operation is the first pass or making the first cut which determines to a considerable degree the preset profile of the structure. The first cut can be made by reference to pegs and poles. When making the first cut by reference to pegs (Fig. 10.1*a*), the grader blade is set to a slope angle of up to 15° so that the cutting end is 15-20 cm from the pegs and is levelled with the outer edge of the front wheel rim. The rear wheel on the same side should ride on the cut bottom.

When using poles (Fig. 10.1*b*), the procedure is as follows. Poles 2-2.5 m high are arranged at a distance of 100-150 m to mark the desired reference line for the grader movement. When doing this the distance from the first cut line to the longitudinal axis of the grader should be taken into account. The grader blade is set likewise when using pegs.

While cutting, the operator directs the machine so that its longitudinal axis is aligned with both poles. A radiator filler plug or a special marker can be used as a reference on the grader.

Proper initial positioning of the blade and machine is of great importance for ensuring high quality of earthwork.

When cutting (Fig. 10.2), the plan angle should be more acute but not less than 30° to preclude sideskid of the motor grader because of the blade load. If the blade is properly set, this load acting normally to the blade surface should be at

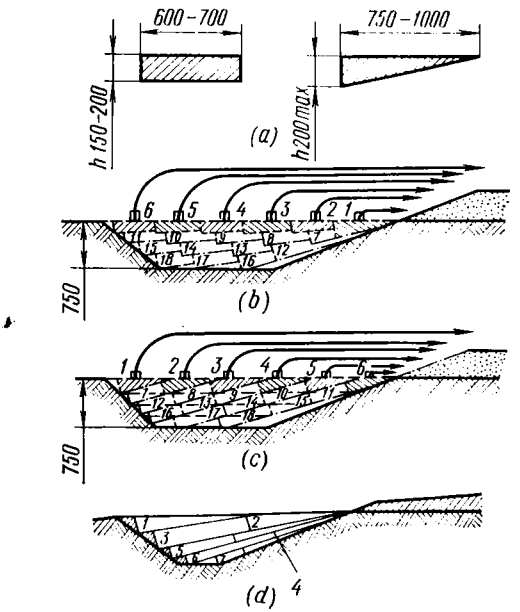


Fig. 10.3. Diagram of soil cutting

(*a*) cut cross section; (*b*) cutting borrow pit with rectangular cuts; (*c*) cutting borrow pit with triangular cuts; (*d*) cutting at ground elevation; *1-18*—numbers of passes

the middle part of the machine. To prevent light and medium graders from skidding some of them have leaning front wheels which displace the machine centroid in the direction opposite to that of skidding. In cutting heavy, wet or compacted soils, the plan angle is increased, at the expense of the amount of soil removed.

The shape and size of spoil depending on the earthwork pattern also affect the productivity of a motor grader. Fig. 10.3 illustrates three possible patterns of blade cutting. Spoil cross section (Fig. 10.3*a*) can be rectangular and triangular,

the former being by about 50-70% greater thus increasing the grader productivity at equal travel speeds.

Soil cutting as shown in Fig. 10.3*b* is used when making embankments and profiling a roadbed. Cutting starts from the inner edge of the borrow pit and is accomplished by layers. The first spoil is triangular in cross section, while the subsequent ones become rectangular. The numbers in the diagram show the sequence of cutting the soil. Such a pattern obviates the need for any additional grading of the borrow pit bottom.

Figure 10.3*c* represents a possible sequence of cutting soil from the outer edge of the borrow pit towards its inner edge. The shortcoming of this pattern is that triangular-section spoil is formed in all the passes and additional grading of the borrow pit bottom is needed.

When making side triangular ditches, it is good policy to perform cutting from the outer edge of the ditch as shown in Fig. 10.3*d*. This results in triangular and rectangular spoil. The soil cut by the blade is displaced along the latter and discharged from its free end in the form of a small bank.

Moving this bank to the embankment is a very significant part of the grader operation: the number of grader passes devoted to soil movement is 60 to 75% of the total number of passes required to make an embankment from the borrow pits.

To decrease the number of passes, i.e. to increase the grader productivity, the following basic requirements are to be observed in earth-moving:

the spoil should be displaced as far as possible during one pass;

the grader should travel at a maximum speed;

the mouldboard should be provided with the extension (if an earthwork plan envisages using a special grader for earth-moving only, both left- and right-hand extensions should be attached to the blade);

the spoil moved to the embankment should be laid in layers approaching the required profile of the embankment.

The blade end should protrude beyond the spoil being moved for 10-20 cm (Fig. 10.4) to preclude spilling of soil through the blade edge (lesser values are used with bound soils). The plan angle should be about 45°. In moving wet and com-

pacted soil, the circle angle is somewhat decreased. Loosened and dry soils are moved with an increased plan angle which allows an increase in the pass length.

The third operation is *levelling of the spoil* and lateral profiling of the earth bed. Since the required blade effort is lower than with previous operations, the blade is set to a maximum angle thus maximizing the pass width (Fig. 10.5). Besides, the blade can be equipped with a wing or banking

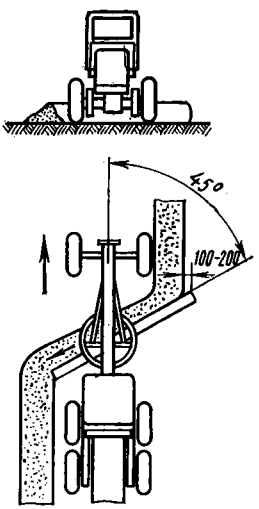


Fig. 10.4. Moving operation

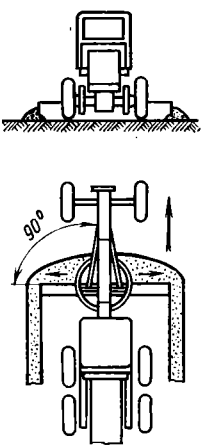


Fig. 10.5. Smoothing operation

extension to level soil in ditches and on slopes. The grader travel speed in levelling should be as high as possible.

Table 10.1 lists the motor grader blade angles recommended for different operations.

To adjust and check the blade position with respect to the horizon in motion, a special device is used (Fig. 10.6*a*, *b*). It is a drum (*4*) freely rotating on a pivot (*9*) with a weight (*12*) attached to it. A pointer (*6*) is secured to the drum. The weight is connected to the drum through a sector (*8*). The device is arranged on the blade.

When the blade is sloped through any angle γ_1, a scale (*7*) linked with the former also tilts. The weight (*12*) being

Table 10.1. Recommended Blade Angles

Operation	Blade angles, deg (lower limit corresponds to heavy soils)		
	plan angle	pitch angle	slope angle
Cutting			
loosened soil	30-35	35-40	15
non-loosened, categories I, II	40-45	30-35	15
Movement			
wet soil	40-50	30-35	11
dry	35-45	35-40	13
Grading	45-60	35-40	18
Levelling			
with compaction	70-90	50-60	2
without compaction	55-60	45-50	3
Slope cutting	60-65	40-45	60
Ditching			
inner slope	35-40	30-35	Repose angle
outer slope	20	40-45	Same
Addition mixing			
dry mixture	35	45	3
bound soil	35-40	45	2

a vertical reference, keeps the pointer (*6*) in the initial position through the sector and the drum. Thus, the deviation of

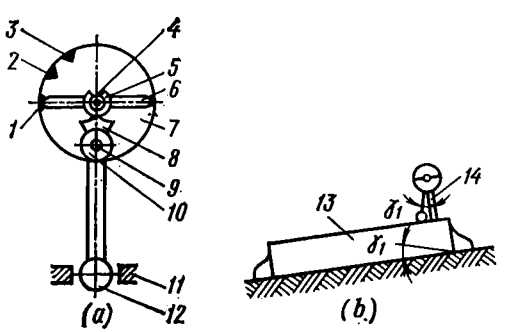


Fig. 10.6. En-route blade slope angle indicator

(*a*) device schematic diagram; (*b*) device mounting diagram; *1*, *2*, *3*—scale marks; *4*—drum; *5*—wire rope; *6*—pointer; *7*—scale; *8*—sector; *9*—pivot; *10*—bearing; *11*—limiter; *12*—weight; *13*—grader blade; *14*—upright

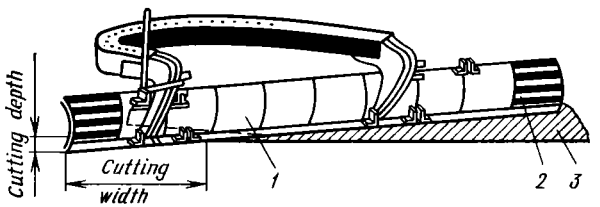


Fig. 10.7. Marking of grader blade
1, 2—vertical and horizontal strips; *3*—fill

a mark on the device scale from its pointer indicates the blade slope angle.

To facilitate checking the cutting depth and width, the blade side can be painted with several horizontal strips, say white and black and vertical strips applied with equal spacing (Fig. 10.7).

Motor grader performance dictates its sphere of application. Thus, depending on type and weight the motor graders should be used as follows.

Light motor graders — road maintenance and repair, i.e. operations which do not require excessive blade effort.

Medium motor graders — maintenance and repair of earth roads, road construction under moderate soil conditions and low volumes of earthwork.

Heavy graders — large volumes of earthwork in the construction of roads, dams, embankments, and during preparatory operations under adverse soil conditions.

10.2. Basic Rules for Operating Motor Graders

Traffic rules stipulate that a road vehicle which is not a truck-chassis-mounted machine be controlled by an operator who carries a special license granted by a qualification board.

Previous to his employment, the operator has to pass a medical examination, and learn safety, fire, and work regulations. Then, after familiarizing himself with the operation of the machine assigned to him, the newly employed operator receives formal certification from the road construction industry.

The assignment of the grader is done in accordance with a special statement indicating the grader's make, series number, engine number, the total number of hours since the machine has been put in operation, the condition of the main units from the beginning of the assignment, and completeness of the machine.

The operator is charged with a number of servicing routines. Prior to working, he should check the condition of the machine, inspect it externally, check the attachment of the main units, the quantity and quality of fuel and coolant, correct defects, if any, idle the engine, test the hydraulics, and perform a trial run of the grader.

While working, the operator should check the readings of the instruments and operation of the engine, transmission, running gear, and implements, and the steering and braking systems. In the event of complications, the operator must immediately shut down the engine and initiate repairs.

After work, the operator should clean the grader of dirt, check the condition of the lubricants, fill the fuel tank, check the water level, or, if winter, drain it.

The efficient use of a motor grader in various earth-moving operations is determined by its productivity. Productivity depends on the type of operations performed, the soil, operation planning, the operator's skill, and other factors.

When profiling a roadbed and gravel roads, grading shoulders, and performing patrol cleaning, the grader productivity is expressed by a section of a roadbed or road constructed (cleaned) per hour, km/h, and is found from the following equation

$$P = LK_t/T$$

where L is the road section length, km; and K_t is the time coefficient of grader utilization ($K_t = 0.85\text{-}0.90$), T is the time spent for construction, h.

In its turn, the time T is determined from

$$T = n_1L/v_1 + n_2L/v_2 + (n_1 + n_2)t_t \times {}^1/_{3600}$$

where n_1 is the number of cutting passes; n_2 is the number of earth-moving passes; t_t is the time needed for turning the grader at the section ends ($t_t = 20\text{-}25$ s); v_1 is the speed at

cutting, km/h; v_2 is the speed of earth moving, km/h; and $^1/_{3600}$ is a conversion factor intended to obtain time in hours.

When making embankments, cutting ditches, constructing roadbeds and performing other heavy jobs, the productivity is measured in cubic metres of soil moved per hour (m^3/h)

$$P = \frac{60NFLK_t}{(L/v_0 + t_t)^n}$$

where N is the shift duration, h; F is the spoil cross section area of a single-pass cut, m^2 (it amounts to 0.05-0.09 m^2 for medium graders and to 0.07-0.12 m^2 for heavy machines); L is the cutting width, m; v_0 is the average operating speed of the graders, m/min; n is the number of passes.

The grader productivity can be increased by:

— shortening dead periods owing to sophisticated operation planning and proper machine maintenance;

— decreasing the required number of passes by advantageously utilizing the machine power, increasing the amount of spoil cut or moved during one pass;

— increasing the cutting width to diminish the fraction of time spent in turning at the end of each pass in the total time of the pass;

— improving the skill of the operator so that he operates the machine at increased speeds.

The efficiency of use and the productivity of a motor grader can be improved by implementing industrial engineering methods, including:

— organizing specialized road construction units equipped with machines of the same type which would promote advanced operation practices;

— implementing a progressive-premium system and piecework payments to provide incentive to the operators to improve their work;

— raising the operators' qualifications;

— introducing advanced maintenance and repair practices;

— increasing the operator's productive time by releasing him from preparatory and fueling work;

— using automatic blade control systems.

10.3. Motor Grader Control

Cab equipment. Though differing in construction and outfit, the cabs of all graders consist of substantially common elements (Fig. 10.8). All the cabs are two-door, all-metal glazed structures to facilitate observation of the working zone. The cab accommodates two seats (*12*) and (*13*), the operator's seat being adjustable in height and reach. The internal walls are lined with a decorative covering.

The cab is equipped with lights, heaters, local ventilation, and a defroster. It houses a steering wheel (*3*), levers and pedals for controlling the engine, transmission, implements and brakes.

To make the operator more comfortable in work, a sun visor, rear-view mirror and pneumatic windshield wipers are provided. The cab also accommodates compressed air bottles (*16*) for starting the engine (in heavy graders), a first-aid kit (*11*) and a fire extinguisher (*17*).

If the grader is equipped with an automatic blade control system, the blade control panel is also installed in the cab. The cab floor is covered with felt and rubber mats to impro-

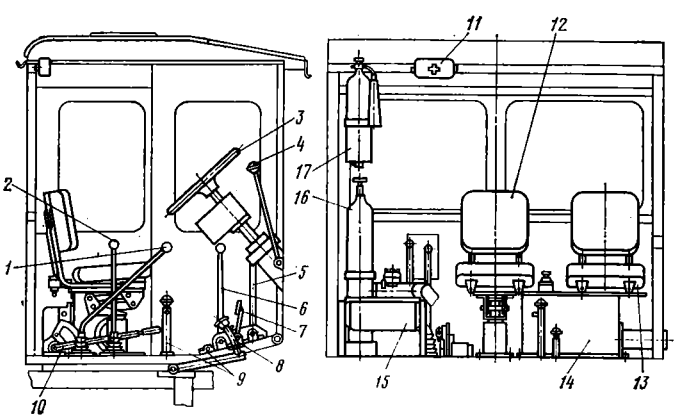


Fig. 10.8. Motor grader cab equipment

1—reversing lever; *2*—gearshift lever; *3*—steering wheel; *4*—operating equipment control lever; *5*—front axle lever; *6*—step-up gear lever; *7*—clutch pedal; *8*—wheel brake lever; *9*—throttle lever and pedal; *10*—hand transmission brake; *11*—first-aid kit; *12*—operator's seat; *13*—additional seat; *14*—heater box; *15*—water heater; *16*—compressed air bottle; *17*—fire extinguisher

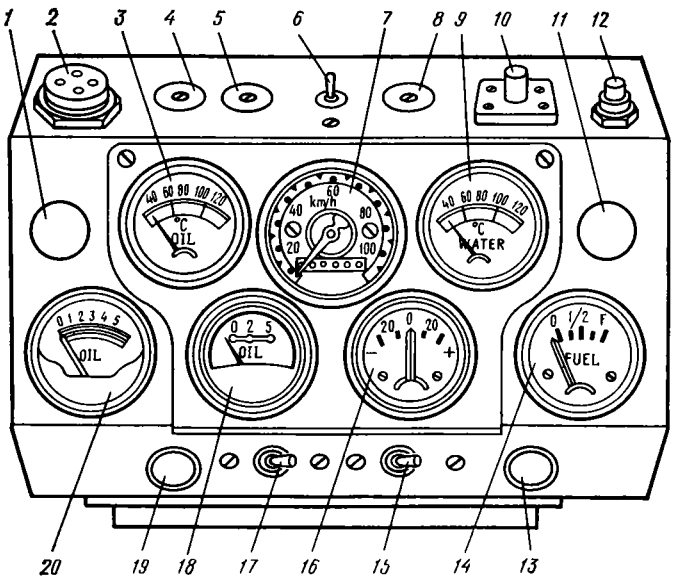


Fig. 10.9. Instrument panel

1, 11—instrument light fixtures; *2*—heater check spiral; *3, 9*—temperature gauges; *4, 5, 8*—pilot lamps; *6*—instrument panel lighting selector switch; *7*—speedometer; *10*—relay; *12*—horn button; *13*—lighting switch; *14*—fuel gauge; *15, 17*—right- and left-hand switches of cab fan; *16*—ammeter; *18, 20*—pressure gauges; *19*—heater selector switch

ve heat insulation and decrease noise and vibration. The cab doors are provided with locks. The doors are fixed in the open position by spring latches secured to the side walls of the cab.

To control and monitor operation of the electric equipment, engine, transmission and hydraulics, a cluster of instruments is mounted on a panel within the operator's view near the windshield.

The grader instrument panel (Fig. 10.9) mounts a speedometer (*7*), a pressure gauge (*18*) for checking pressure in the gearbox lubrication system, a pressure gauge (*20*) for checking pressure in the engine lubrication system, a temperature gauge (*3*) for checking engine oil temperature, a tempera-

ture gauge (*9*) for checking coolant temperature, an ammeter (*16*) for checking functioning of the electric equipment charging circuit, a pilot lamp (*8*) illuminating if the storage battery is discharging, a turn signal pilot lamp (*5*), a fuel gauge (*14*), cab heater pilot lamp (*4*) and check spiral (*2*), a relay (*10*) adapted to cut out the heater when a preset temperature limit is exceeded. The instruments are illuminated through slits in light fixtures (*1*), (*11*).

Grader control hints. *Prior to starting the engine and trial idling the grader*, check the amount of lubricant and the oil level in reservoirs against the lubrication chart, the coolant level in the engine cooling system and the electrolyte density in the storage batteries.

Start the engine according to its operating instructions. The transmission and control levers should be neutral, the parking brakes should be applied.

After starting the engine, check the instruments, primarily the engine oil pressure gauge: it should read 0.35-0.5 MPa, and the ammeter. The ammeter pointer should deflect rightward at the engine speed of 1000-1100 rpm which indicates proper charging of the storage batteries.

If the oil pressure gauge reads zero, shut down the engine immediately.

If a grader is equipped with a pneumatic system, the receiver pressure should be 0.6-0.7 MPa.

With the engine idling, make sure that no fuel, water or antifreeze, oil and air leak through the joints. Never run the engine idle (at 600 rpm) for more than 10 min.

Load the engine only after the coolant and oil temperatures reach 50-70°C.

To start the motor grader, release the parking brake, depress the clutch pedal, engage gear, give a warning signal, gradually release the clutch pedal with synchronously increasing fuel supply (depressing the throttle pedal) and start movement. Contrary to an automobile, the grader can be started with any gear engaged.

The motor graders with a hydromechanical transmission have no clutch so that the machine is started after engaging the gear and releasing the service brakes.

Prior to moving, make sure the steering system, signal lights and horn are operable. To this end, turn the steering

wheel to both sides several times with the machine at standstill. Then check the turn signals, the stop light and the horn. Test the service brakes immediately after starting the grader.

Motion control is effected mainly by manipulating the steering wheel and changing speed, i.e. selecting gears to suit the motion conditions. In ditching mode, the implement position is also subject to control.

To change gears with a mechanical gearbox, observe the following main rules to ensure quick and smooth gearshifting.

To select a higher gear, delay the gearshift lever slightly in the neutral position to equalize the circumferential velocities of the gear rims and slides and then move it quickly to the desired position.

To select a lower gear, fully depress the clutch pedal, set the gearshift lever neutral, slightly release the clutch pedal to equalize the gear speeds, disengage the clutch and engage the desired gear.

The double gearshifting ensures absolutely noiseless engagement and protects gears against rapid wear or tooth breakage.

The reverse gear can be engaged only after the motor grader is at a standstill.

A heavy grader is provided with a brake (*10*) (Fig. 2.2) for stopping the output shaft during gearshifting. To select higher gear, smoothly depress the clutch pedal till its force starts to rise which is indicative of equalizing of input and output gear speeds, disengage the gear, bottom the clutch pedal (the gearbox input shaft will be braked) and engage a higher gear.

When selecting a lower gear the brake exerts a negative effect. To preclude braking of the output shaft of the clutch, hence of the gearbox input shaft, depress the clutch pedal up to the moment when the pedal force starts rising drastically (now the clutch is already released but the brake is not yet applied).

To ensure a more positive selection of a lower gear, accelerate the output shaft of the clutch. To this end, release the clutch, set the gearshift lever neutral, release the clutch pedal, accelerate the engine, again depress the clutch pedal and shift the gearshift lever to a lower gear position.

The first gear is used mainly for heavy-duty work (rough profiling, ripping), the second gear for cutting and earth-moving, the third for grading and snow ploughing. The higher gears are employed in travelling and selected depending on the road condition and surface type.

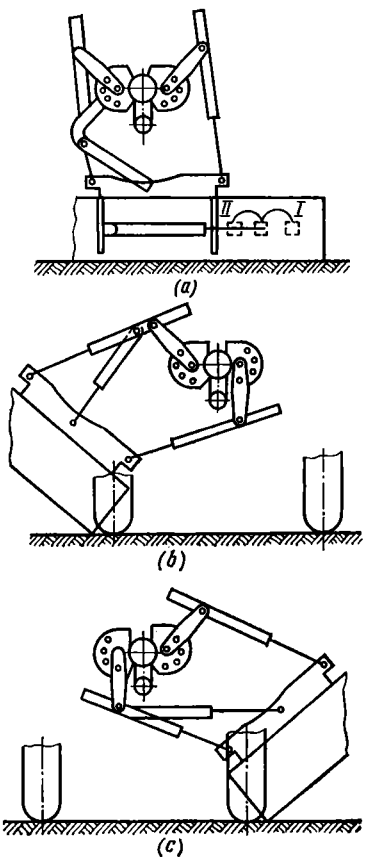


Fig. 10.10. Diagram of draft frame and blade suspension lever positions

(*a*) operation and travelling; (*b*) left-hand sloping; (*c*) right-hand sloping

An important element in grader control is braking. It can be used to discontinue machine movement or to stop it abruptly when an unexpected obstacle is encountered.

In the first case, brakes should be applied smoothly by gradually increasing the pedal force. Rapid application of brakes may cause skidding which considerably diminishes the efficiency of braking. Strong and abrupt braking may lead to sideslip. Should sideslip occur, quickly release the brake pedal, straighten the machine by the steering wheel and re-apply brakes.

Operating equipment control includes setting the blade to the initial position and manipulating it in the course of work.

Setting the blade to the initial position considerably affects the grader productivity and is characterized by three angles (Fig. 1.8): plan angle, slope angle and cutting (or pitch) angle.

When the plan angle is decreased, the speed of soil move-

ment along the blade increases, hence increases the amount of soil displaced per unit time. Therefore it is necessary to minimize the plan angle. However, decreasing the plan angle leads to sideslip of the grader which impedes control. On the other hand, decreasing the blade plan angle diminishes the soil displacement distance.

The blade slope angle affects the rate of soil movement along the mouldboard which decreases as the angle is increased thus impairing the grader productivity.

The blade cutting angle determines the soil resistance to cutting which decreases when the angle is diminished. Thus, the optimal positions of the blade differ with the grader operating conditions (see Table 10.1).

The plan and slope angles are set by the operator with the aid of the hydraulic system. The pitch (cutting) angle is adjusted by thrusting the blade against the soil. The blade's shift to both sides for grading and sloping is carried out by means of the hydraulic drive. Fig. 10.10 illustrates extreme positions of the blade.

Blade control in the course of work is confined primarily to adjusting the amount of cut.

When operating the levers of the implement control distributor, observe the following main rules: engage the lever quickly and positively, never apply excessive force to the lever, the force should be just sufficient to keep it in the engaged position; immediately release the lever as soon as the implement reaches its extreme position.

To stop a mechanical gearbox grader, decelerate it by releasing the throttle pedal, push the clutch pedal and set the gearshift lever neutral. Apply brakes to stop the machine and shut down the engine according to its operating instructions.

Chapter 11

EARTH-MOVING OPERATIONS

11.1. Roadbed Construction Procedure

A roadbed construction is a complex, multi-operation work carried out in a definite sequence with the use of various road-constructing machines. The work is divided into preparatory, main and final operations.

Preparatory operations include cleaning the land of trees, stumps, bushes. These operations are carried out by mechanized units including caterpillar tractors with bulldozers, stump-pullers, tree-dozers, bush-cutters.

When performing preparatory operations, all measures should be taken to minimize the impact upon the environment. The land should be cleaned of trees and bushes with the maximum protection of surrounding woods. Valuable trees should be replanted. When preparing the roadbed, avoid using soil from borrow pits for making embankments or limit the borrow pit depth to 1-1.5 m. After cleaning the land, start marking the roadbed, i.e. mark its boundaries and configuration on the terrain with pegs up to 1 m long.

The direction and width of the roadbed elements (embankment foot and borrow pit edges) are pegged out lengthwise and widthwise of the land. Roadbed elevation is determined by the peg height and inscriptions applied to them. The elevation pegs are arranged outside the land lines to preserve them up to the end of the earthwork with a spacing of not above 100 m or 10-20 m at places where the longitudinal profile changes occur. The pegs marking the roadbed lines should be driven in 25-50 m or 10-15 m at curvatures.

Main earthwork includes making embankments, ditches, borrow pits, and water drains. These operations are performed with the use of earth-moving and road-building machines such as motor graders, scrapers, bulldozers.

Finishing operations include grading the borrow pit bottom, smoothing slopes and forming the camber (crown) according to the specifications.

After forming the roadbed, the surrounding area is subject to reclaiming (i.e. returning the vegetation layer of soil cut and moved aside at cleaning to the exposed soil portions of the borrow pits.

Slopes of embankment and water draining structures, likewise the pit slopes, are reinforced usually by sowing perennial herbs after applying a vegetation layer 10-15 cm thick to the slopes. The slopes are also reinforced with slag-clay or clay protective layers, or soil treated with binders.

The roadbed is constructed by a combined use of various earth-moving and road-building machines. Proper selection of specialized team equipment as well as its leading **ma-**

Table 11.1. Recommended Sets of Equipment for Constructing Different Elements of Roadbed

Cross section type	Height of fill or depth of cut, m	Leading machine	Complementing machines	Soil group	Coverage, m
Embankment filled from borrow pits	Up to 0.5	Motor grader	Scarifier, bulldozer, roller	I-IV	250-500
Embankment filled from borrow pits at both edges	Up to 1	Motor grader, bulldozer	Scarifier, roller	I-IV	500-1000
Ditto	1.25-1.5	Elevating grader	Motor grader, bulldozer, scraper, roller	I-III	500-1000
Alternating embankments of different height, depth and length	Not limited	Scraper, excavator	Bulldozer, dump truck, motor grader, roller	I-III	Sections of concentrated work
Cut-and-fill slope at longitudinal earth moving	Not limited	Scraper	Motor grader, bulldozer, roller	I-III	250-500
Finishing and grading	Up to 2.5-4	Motor grader, bulldozer with grading implements	Motor grader	I-III	500-1000
Ditto	4.5 and more	Special implements on excavator, grading excavator	Same	I-III	500-1000

Table 11.2. Making Embankment from Borrow Pits by Mechanical Plant

Operation	Coverage, m	Machine
Removal of vegetation layer of soil	270	Bulldozer
Layer-by-layer filling of embankment. Levelling. Layer-by-layer compacting. Filling breaks in roadbed. Making provisional ramps	540	Motor grader, bulldozer, roller
Layer-by-layer additional filling with soil levelling and compacting	270	Scraper, bulldozer, roller
Elimination of provisional ramps. Formation of trench. Grading of embankments and slopes	540	Motor grader, bulldozer
Movement of vegetation soil to slopes and bottom of borrow pit. Final grading of slopes and pit bottom	540	Bulldozer, motor grader

chine intended to perform the bulk of operations hence determining the productivity of the entire team is of utmost importance.

Labour productivity in integrated teams is increased by employing machines according to their design and operation capabilities. For instance when *separately filling an embankment by specialized teams*, the lower part of the embankment is built from the borrow pits by grader or bulldozer teams, while the top is formed by scraper teams. This allows a sophisticated use of particular machines in compliance with their basic purpose. Bulldozers move earth through distances up to 15 m, motor graders construct the embankment up to 0.5 m high, while the scrapers transport and partially compact soil on the top layer of the embankment.

When using a method of *continuous integrated mechanized construction of a motor road*, specialized teams successively perform their work advancing along the route so that a finished road is left behind the last machines of the group. This provides for continuous and uniform accomplishment of the earthwork.

The road section length with a continuous method depends

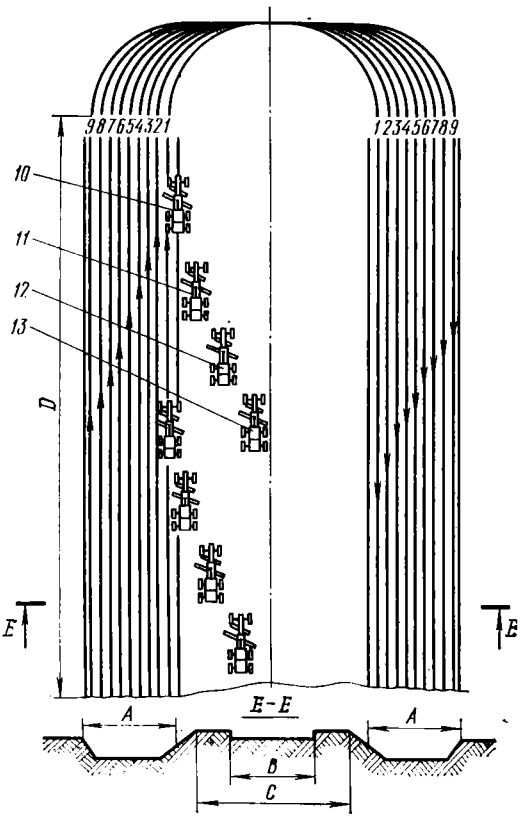


Fig. 11.1. Organization of earthwork for four motor graders

A—borrow pit width; *B*—embankment width; *C*—trench width; *E*—coverage; *1-9*—soil windrows; *10-13*—motor graders

on the ground relief, location of service lines, terms and volume of work. To better supply of necessary materials, and centralize management, it is recommended to concentrate work at relatively short sections from 1 to 1.6 km long.

The motor graders are used as leading machines for making embankments, in grading and finishing. They are complemented with other machinery selected to optimally mechanize the entire process and suit the productivity of the leading machine

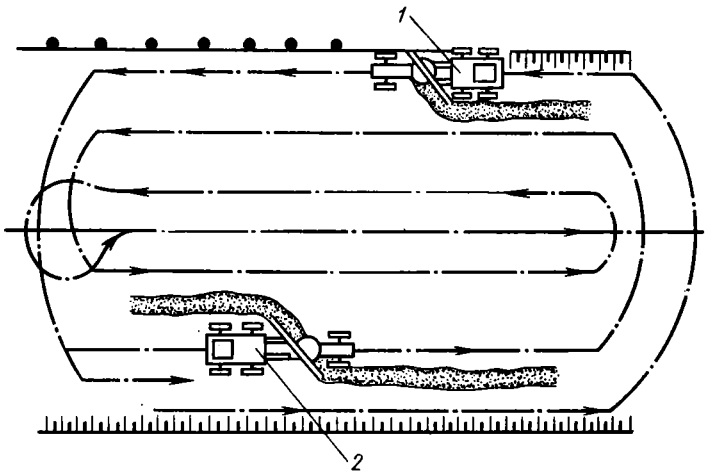


Fig. 11.2. Organization of earthwork for two motor graders

Table 11.1 lists recommended sets of equipment (also called mechanical plants) for performing different operations in constructing the roadbed and indicates the leading machines of the sets.

Table 11.2 indicates a recommended sequence of operations for making a roadbed embankment from side borrow pits by a mechanical plant with a motor grader as a leading machine.

Owing to their versatility, motor graders can be used in single. However, such a use is expedient only when constructing roadbeds with small volume of earthwork or for repair operations.

To ensure high rates of construction of a roadbed for projects with a large volume of earthwork, it is better policy to use two to four machines at a time within the integrated mechanized unit. Fig. 11.1 illustrates operation of four heavy motor graders for filling an embankment from borrow pits with lateral movement of soil through 10 m.

A motor grader (*10*) cuts soil from the borrow pit by a left- or a right-hand end of the blade depending on the direction of its movement. Soil is cut layer after layer from the inner

edge of the pit. The spoil is displaced to the center line of the embankment by other three motor graders (*11*), (*12*), (*13*) operating in an echelon formation.

When the embankment is to be narrow, it is advisable to use two motor graders (Fig. 11.2). A heavy grader (*1*) cuts the soil from the inner edge of the borrow pit and a medium grader (*2*) moves and grades the spoil. The graders move one after another in circular passes.

11.2. Profiling Earth Roads

Profiling of an earth road is forming a lateral cross section of a roadbed in the form of small fills by the spoil from side

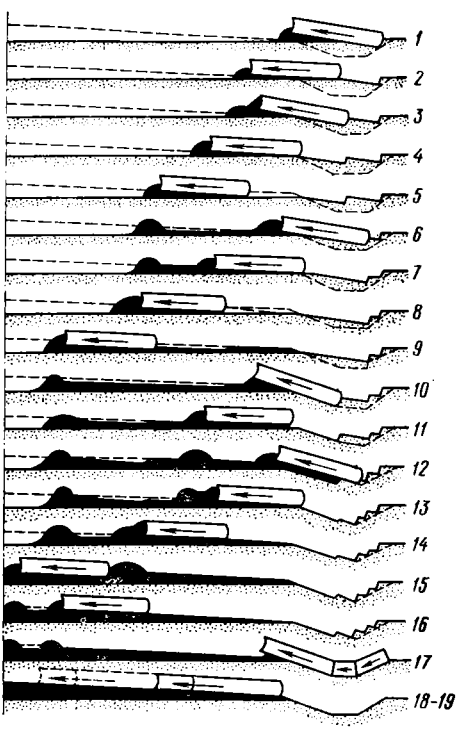


Fig. 11.3. Motor grader passes (*1-19*) in profiling roadbed

ditches or borrow pits. The spoil from the side ditch being cut is moved to the road center line to elevate the carriageway.

To increase productivity and efficiency of earth road profiling, prior to beginning the work the required set of machines and auxiliary equipment, operation patterns and sequence, number of grader passes are to be determined. With this in mind the engineering personnel compiles graphs and diagrams based on the afore-mentioned considerations and proposes the blade setting angle, the amount of cut, the machine speed and other parameters for each operation.

The length of pass or coverage should be the maximum possible for profiling the roadbed with a motor grader during one or two shifts. The coverage is usually 0.5 to 1 km. Heavy graders are capable of constructing from 1.5 to 2 km of earth road per shift. Figure 11.3 illustrates a diagram of profiling an earth road with flat-bottom ditches.

Table 11.3. Blade Setting Angle and Penetration for Profiling Roadbed

Pass No.	Operation	Blade setting angles, deg.			Penetration, mm
		plan	pitch	slope	
1	Cut	35	28	9	200
2	Move	50	41	1	—
3	Cut	35	28	11	200
4	Move	50	41	1	—
5	Move	50	41	1	—
6	Cut	35	29	11	150
7	Move	50	41	2	—
8	Move	50	41	2	—
9	Move	50	41	2	—
10	Cut	35	29	19	150
11	Move	50	41	3	—
12	Cut	35	29	17	150
13	Move	50	41	3	—
14	Move	50	41	3	—
15	Levelling	50	41	3	—
16	Levelling	50	41	3	—
17	Ditch finishing	45	41	19	—
18	Levelling	55	41	3	—
19	Levelling	55	41	3	—

For simplicity only a half profile of the roadbed is shown. Profiling consists essentially in successive circular passes of the motor grader along both sides of the roadbed. The desired roadbed profile is shown in the upper part of the diagram. The first pass cut is started from the outer edge of the ditch with deep penetration of the blade. The spoil is filled onto the inner edge. During the second pass the windrow is moved by the blade along the embankment top. Thus the desired profile is gradually obtained by cutting and moving the spoil along the embankment. Cutting is completed during pass *12* and the spoil is moved to the roadbed center line by two passes *14* and *15* and is then levelled in pass *16*. The final stage of profiling consists in finishing the ditch by a standard back sloper mounted on the blade (pass *17*) and finish levelling of the roadbed (passes *18* and *19*). To perform this final operation the grader blade is equipped with an extension.

The sequence of profiling operations according to the above-mentioned pattern and the respective blade setting angles are indicated in Table 11.3. The table also gives the amount of cut (penetration) for each pass.

Profiling of an earth road may expediently be made by two motor graders. One of the graders cuts and the other, equipped with the blade extension, moves the soil. Therefore, the idle time spent on resetting of the blade and the implements is decreased.

11.3. Making and Finishing Banks and Cuttings

Filling embankments from borrow pits consists in cutting and moving spoil by a motor grader during longitudinal passes of the machine. Borrow pits are cut alternately on both sides of the embankment and spoil is moved towards its center line.

Borrow pit cutting is started from its inner edge (Fig. 11.4). Spoil has to be moved both in the pit and on the embankment. The spoil is filled in a definite pattern depending on the embankment height.

When filling embankments up to 0.6-0.7 m high, the windrows are arranged tightly (Fig. 11.5*a*). In this case each succeeding windrow is tightly pressed to the preceding one

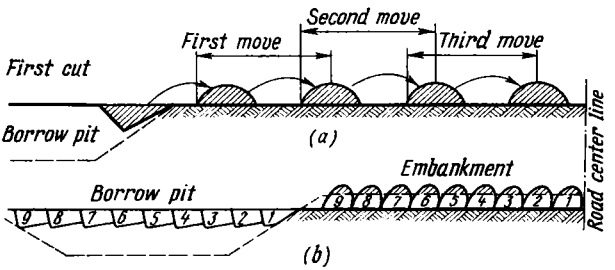


Fig. 11.4. Cutting borrow pit

(*a*) soil cutting and moving; (*b*) soil laying; *1-9*—motor grader passes

which is penetrated by the blade through 5 to 10 cm. Such a method of windrowing gives one wide and consolidated bank of spoil which is 10-15 cm higher than each separate windrow and is twice as great in the volume.

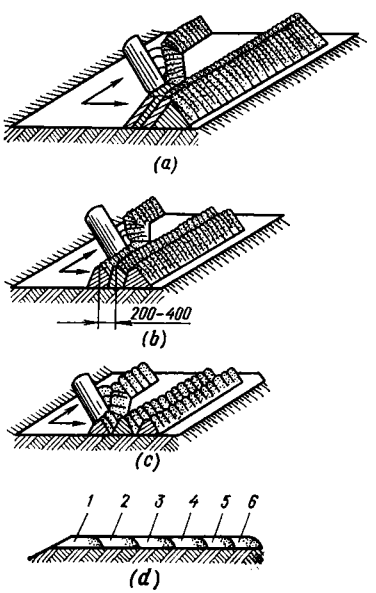


Fig. 11.5. Diagram of laying soil in embankment

(*a*) tightly; (*b*) with overlap; (*c*) with base contact; (*d*) in layer with assigned camber; *1-6*—motor grader passes

If the embankment is to be 0.4-0.5 m high (Fig. 11.5*b*), the windrows are so arranged that the distances between their crests are from 20 to 40 cm.

In filling the embankments up to 0.25 m high (Fig. 11.5*c*) the windrows should contact each other only at their bases.

With the embankment height not exceeding 15 cm, it is advisable to fill the spoil in one layer, rather than in windrows, moving it from the edge to the center line of the road to obtain the desired camber (Fig. 11.5*d*).

The embankment is filled layer-by-layer up to the de-

sired elevation. If the filled spoil is to be consolidated by settlement, rather than by compacting each layer, the windrows are arranged tightly to each other. In case of a permanent coating, the embankment is filled and consolidated layer-by-layer.

The lowermost layer can be filled by two methods. According to the first method the windrows are arranged so that only their bases are in contact and are then graded by the blade to obtain a fill from 20 to 30 cm high. With the second method the windrows are arranged with building up from the fill edge to its center line. The first windrow is moved to the embankment edge and is partially graded, the second windrow is moved over the first one, the third over the first and the second with partial grading of each windrow.

The filled and graded layer should be consolidated. The second layer of windrows is arranged with partial overlapping from the center line to the end of the embankment; to make the edges more compact several last windrows are arranged tightly to each other. After this layer of spoil is graded and consolidated, the total height of the embankment becomes 0.6-0.7 m. Levelling is the final operation for filling the embankment from borrow pits.

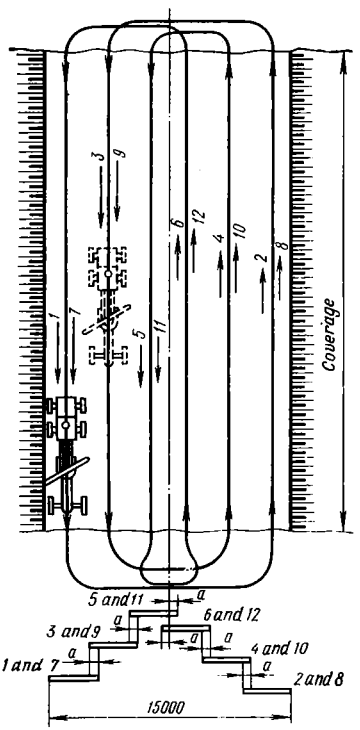


Fig. 11.6. Layer-by-layer smoothing of embankment soil by circular passes

(*a*) overlap of previous pass for at least 300 mm; *1-12*—motor grader pass numbers

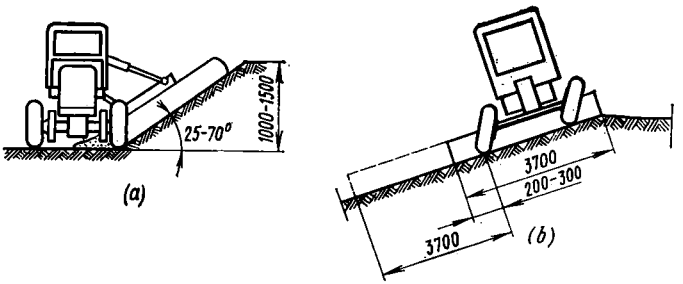


Fig. 11.7. Embankment sloping
(*a*) slope of 25-70°; (*b*) steepness 1 : 3

If the coverage exceeds 500 m, the roadbed surface is levelled by longitudinal circular passes along the embankment from edges to the center (Fig. 11.6). The motor grader blade is set to a plan angle of 60-90° and a pitch angle of up to 50°. The blade slope is maintained according to the desired profile of the road. The passes should overlap for at least 0.3 m widthwise.

If the coverage is between 100 and 150 m, it is advisable to level the surface according to a shuttle pattern with turning the blade through 180°, i.e. using the reverse gear of the motor grader as a forward one.

If the coverage is less than 100 m, the shuttle pattern is somewhat changed: the motor grader moves backward in a reverse gear without turns. To decrease the idle time in this case, the highest reverse gear is engaged.

The construction of the embankment is completed by finishing slopes and levelling borrow pit bottoms.

Finishing inner and outer slopes of a borrow pit up to 1 m high is effected by means of a back sloper mounted on the motor grader blade. The slopes are finished by one or two longitudinal passes of the machine. The spoil is graded over the pit bottom or moved to the embankment. Slopes up to 0.6 m high are graded by the grader blade set to the required slope angle. The outer slope of the borrow pits and ditches from 1 to 1.5 m at an angle of 25 to 70° is graded and finished by the grader blade shifted outside of the frame (Fig. 11.7*a*). To improve stability in these operations the front wheels of the light and medium graders are leaned towards the slope.

The slopes of 1:3 are graded in 2 or 3 passes. During the first pass the upper part of the slope is graded (Fig. 11.7*b*) moving along the edge; the lower part is graded during the reverse pass. The passes should overlap each other for 20-30 cm widthwise. The operation is repeated till the slopes are completely finished.

Levelling borrow pit bottoms with the use of motor graders is shown in Fig. 11.8. According to this pattern two pits are graded simultaneously in two passes. Grading is started from the base of the inner slope towards the outer slope. The blade plan angle is 60-70°, the pitch angle is 40-50°; the slope angle depends on the slope of the pit bottom. The grader moves from one pit to another through specially organized passages.

If the left- and right-hand borrow pits are separately graded, then the machine turning at the ends of the passes is impared.

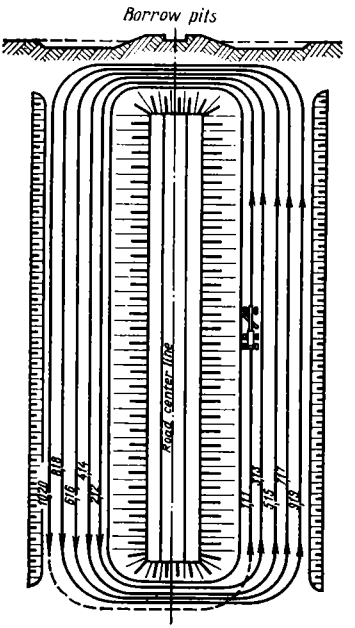


Fig. 11.8. Levelling borrow pit bottom

1-20—numbers of motor grader passes

If embankments over 1 m high are filled with scrapers or other earth-moving equipment, finishing and grading operations are also accomplished by motor graders.

The spoil is levelled by circular passes starting from the fill edges towards the center. The blade plan angle is 70-90°, the pitch angle 40-50°, and the slope angle 1-3°.

When making an embankment on shallow slopes, it should be taken into account that the amount of spoil removed from the uphill pits exceeds that from the downhill pits. When constructing an embankment on a slope with making one wide uphill pit, the motor grader performs unidirection-

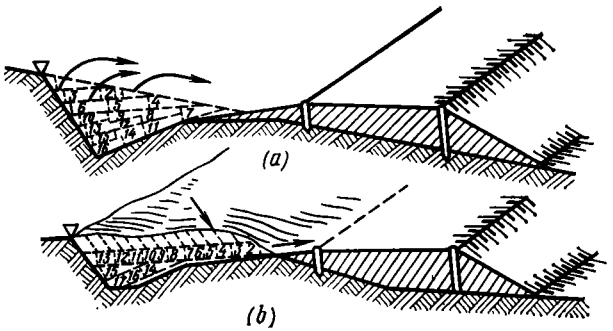


Fig. 11.9. Constructing cut-and-fill embankment
(*a*) soil surface cutting; (*b*) soil undercutting; *1-17*—numbers of motor grader passes

al passes cutting soil by the right- and left-hand ends of the blade alternately.

A cut-and-fill roadbed can be built on slopes up to 20° steep with the use of motor graders. Employing motor graders for making a roadbed on slopes steeper than 20° is not expedient since the hazard of lateral turning over drastically decreases their productivity. On such occasions powerful bulldozers are to be used, while the motor graders are to perform finishing operations.

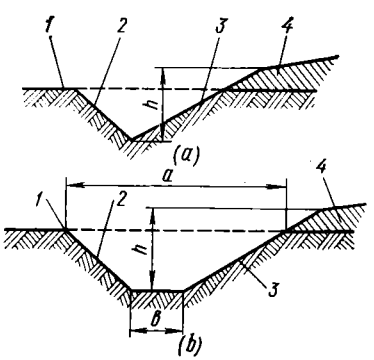


Fig. 11.10. Side ditch profiles
(*a*) triangular; (*b*) flat-bottom; *1*—outer edge; *2,3*—outer and inner slopes; *4*—fill; *a*—top width of ditch; *b*—bottom width; *h*—depth of ditch

When making a roadbed by a cut-and-fill method with the use of a motor grader, soil is removed by surface cutting (Fig. 11.9*a*), or undermining with the blade (Fig. 11.9*b*). In the first instance, the soil is removed from the outer edge of the cut and is moved onto the roadbed to the opposite edge of the embankment. In the second case, soil is cut from the inner edge of the cut and is moved layer-by-layer at the

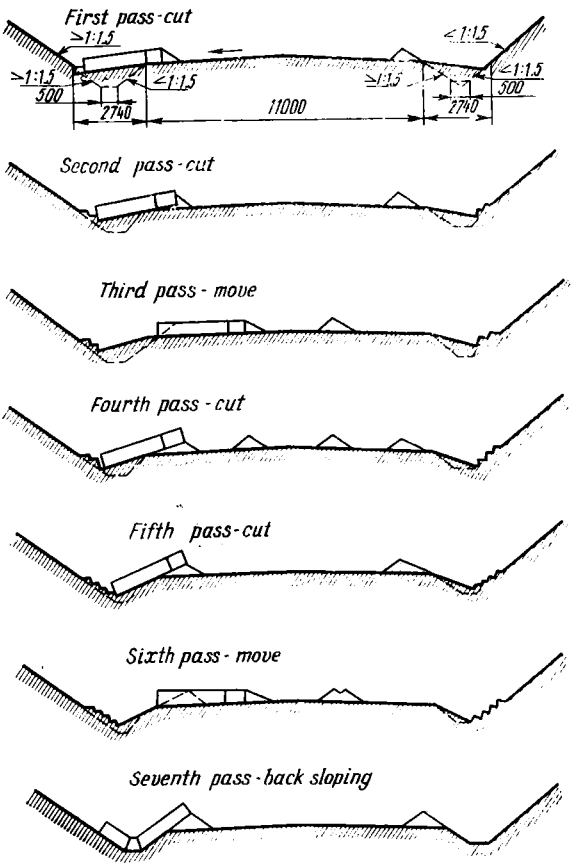


Fig. 11.11. Sequence of passes for cutting side ditch

level of the fill. When soil is undermined at the bottom, its top layer drops down by gravity. The spoil obtained after each undermining is tipped over to the embankment. If the top layer does not drop down after undermining but forms an overhang, it should be ruined. Soil is undermined during a forward pass and moved during a reverse one.

Making side ditches is one of cutting operations in constructing a roadbed. Side ditches are made when building roads

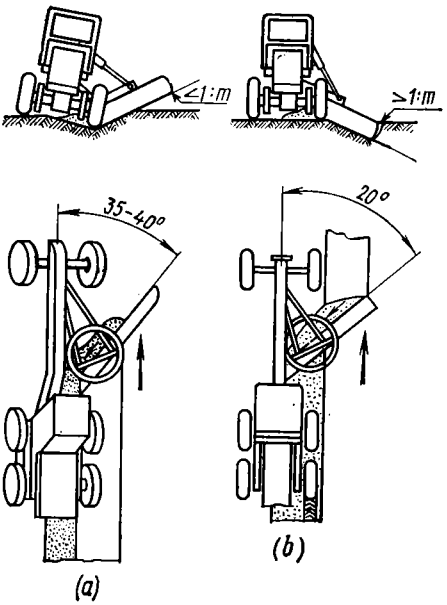


Fig. 11.12. Motor grader operating mode for making side ditches (*a*) cutting inner slope; (*b*) cutting outer slope

in depressions, at zero elevations and on shallow embankments up to 0.5 m high. If a roadbed section is made by a cut-and-fill method, one ditch is provided on the uphill side. No side ditches are made in case of a sandy soil and embankment higher than 0.5 m. The side ditches cut by motor graders may be triangular or flat-bottom in cross section (Fig. 11.10*a*, *b*).

Side ditch depth depends on the roadbed width and soil type. With a roadbed wider than 11 m, side ditch depth is from 0.5 to 1.2 m, if the roadbed width is less than 11 m, the ditch is from 0.4 to 0.9 m deep; the lower limit corresponding to sandy loams, the upper one to clay loams. The side ditch slopes are to be 1:1.5 but when cut by motor graders the inner slope may be 1:2 and 1:3. The ditch flat bottom is made from 0.4 to 0.5 m wide.

The side ditch longitudinal gradient is similar to that of the road but should not be less than 0.5% or more than 5%.

The side ditches are worked by the grader blade, their slopes are finished and bottom is levelled by a back sloper mounted on the blade. Side ditches up to 0.5 m deep are cut by light and medium graders, deeper ditches by heavy machines.

Cutting and removal of spoil from the ditches are carried out by the blade (Fig. 11.11). During the first pass the blade is so positioned that its end cuts soil near the outer slope 20-25 cm away from the marking pegs. Then the blade slope angle is increased and the cutting pass is repeated to move the spoil first to the edge of the inner slope and, during the next pass, to the roadbed. The ditch is cut down to grade by alternating these passes. The last pass is cleaning and finishing the ditch bottom and slopes with the use of a back sloper mounted on the blade. The operating positions of the motor grader and its blade during side ditch cutting are illustrated in Fig. 11.12.

When cutting the inner slope, the blade is set to a plan angle of 35-40°. The pitch angle is minimized, while the slope angle is adjusted according to the assigned slope base. The right-hand wheels of the machine should move along the ditch bottom. When cutting the outer slope, the blade is set to a plan angle of 20° and the pitch angle is averaged.

11.4. Earthwork Quality Control

Earthwork quality control which is a must for any earth-moving operations resides in systematic checks of adherence to basic requirements outlined in the design documents, specifications and instructions in force. For instance, embankment quality control should include checks of foundation for correspondence to technical documents, tests of soil in borrow pits and cuttings intended for filling the embankment, observation of placement and consolidation of spoil.

Test samples of soil are taken uniformly throughout the structure height and area. This allows a simultaneous check of densities of all layers in different parts of the embankment. Loose portions of the embankment detected as a result of inspection are subjected to additional compaction.

Check results are recorded in special registers. Earthwork quality is also checked during acceptance of an earth strucg ture. While accepting cuttings and embankments, tracin-

of the structures, edge and bottom elevations, gradient and lateral dimensions of drains, steepness and reinforcement of slopes, location of borrow pits, berms, catch-water drains, soil consolidation should be checked. When checking dimensions and gradients of earth structures, their deviations from the design values should be determined. Deviation should not exceed the limits indicated in Table 11.4.

Table 11.4. Permissible Deviations of Earth Structures

Description	Deviation	Check method
Deviation of edge marks or earth structure center line, m	0.05	Levelling
Deviation of ditch bottom, gradient, %	0.0005	Levelling
Decrease of minimum gradients of ditch bottom	Impermissible	Levelling
Narrowing of roadbed	Impermissible	To be measured in 50 m
Deviation of roadbed camber curved junction, m	0.1	To be measured in 50 m
Increase of slope steepness	Impermissible	To be measured in road cross sections
Deviation of ditch lateral dimensions, m	0.1	To be measured in 50 m
Deviation of filled berm width, m	0.15	To be measured in 50 m
Decrease of side ditch lateral dimensions	Impermissible	To be measured in 50 m

Chapter 12

CONSTRUCTION OF IMPROVED EARTH ROADS

12.1. Arrangement of Trench in Roadbed

The trench intended for placing foundation materials (sand, gravel, ballast) and road coating is a cutting, 0.35-0.40 m deep extending lengthwise of the roadbed center line. The trenches are cut by motor graders. The work starts with mar-

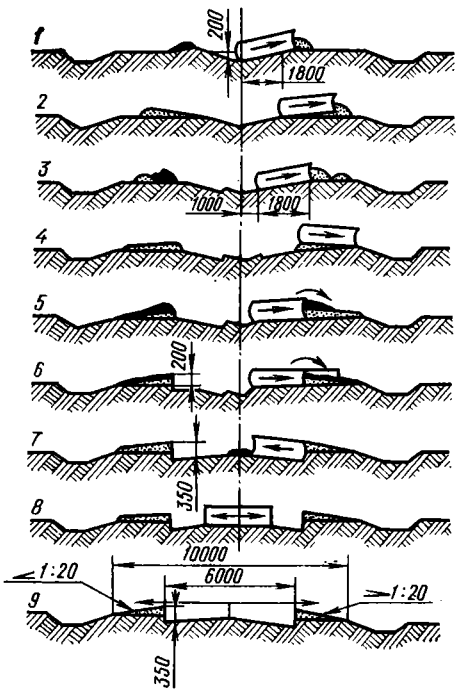


Fig. 12.1. Making trench in finished roadbed

1, 3, 5-7—soil cutting; *2, 4*—moving; *8*—trench bottom smoothing; *9*—finished trench

king the land and checking correspondence of the roadbed actual elevations to the design ones. The trace is marked with pegs spaced through 50-100 m and banged 10-15 cm away from the roadbed edge.

The trench can be cut either in a finished roadbed or simultaneously with filling the latter, which depends on the adopted procedure for constructing the roadbed and pavement, and the embankment height.

The trench is made in a ready roadbed (Fig. 12.1) when it is not planned to place the pavement immediately after constructing the roadbed.

To make the trench, soil is cut from the upper part of

the embankment by circular two-way passes of a motor grader and is moved to the shoulders. During the first pass lengthwise of the trench, soil is cut by the blade 12-15 cm below the trench bottom elevation and the spoil is moved to the shoulder by the second pass. During the third pass the blade is set to a penetration of 3-5 cm below the trench bottom and cutting is performed 1 m away from the trench center line. During the fourth pass the two windrows are spread over the shoulder. The fifth pass is the most vital: it involves cutting the border between the trench and the shoulder. The blade slope angle should not exceed 6° and the plan angle should be from 40 to 45°. The spoil from the blade end is placed tightly on the shoulder and is consolidated at the shoulder border line. To strictly define the shoulder border line during the fifth pass, it is advisable to mark the trench edge by banging pegs in 15-20 m. The sixth pass is intended to finish the shoulder-to-trench joint, while two subsequent passes are aimed at finishing and profiling the trench bottom. These operations can be performed with a blade extension to decrease the required number of passes.

When the pavement is to be placed immediately after filling the roadbed, the trench is made concurrently with the latter. There are various methods of trench construction which depend on the embankment height.

If the embankment is shallow (up to 0.3 m), the spoil from the borrow pits is not moved towards the roadbed center line but is placed along the shoulders with grading it to the required slope (Fig. 12.2).

The spoil is cut from the sides and is windrowed towards the road center line with blading it to the required profile. The blade plan angle for spreading should be from 60 to 70°, for finishing from 50 to 70°. While finishing the shoulder, the grader left-hand wheels should move along the trench bottom and the right-hand wheels along the shoulder. The blade is so positioned that excessive soil is moved towards the trench.

If the embankment height exceeds 0.3 m, the trench is made as follows. The lowest layer of the embankment is filled and consolidated in a regular way. The upper layers from the road center line to the borders of the future trench are placed with overlapped windrows; while those on the shoulder are

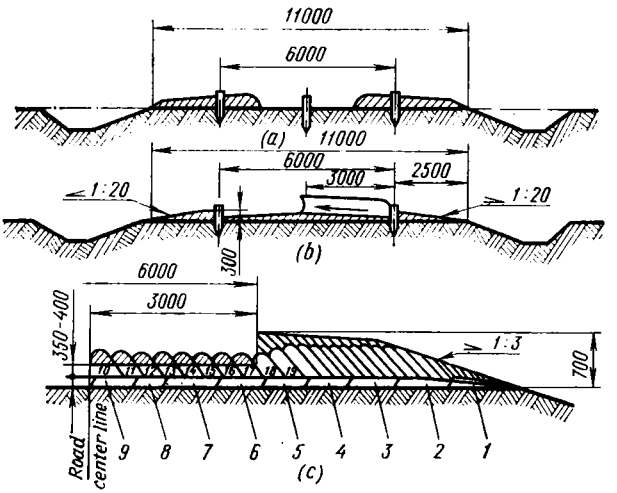


Fig. 12.2. Making trench concurrently with embankment
(*a*) shoulder filling; (*b*) trench profiling; (*c*) trench construction diagram; *1-19*—numbers of motor grader passes

arranged in windrows tightly adjoining each other. The layer filled on the shoulders becomes higher than the trench fill. The windrow crests in the trench zone are cut and moved to the shoulders. The work is then continued in a conventional manner.

If the roadbed is made in cuttings, the trench is cut down to line by scrapers which remove spoil outside of the cutting. The trench is finished and levelled by motor graders.

Trench levelling can be performed in eight passes of the motor grader (Fig. 12.3). The first and second passes are carried out along the trench edges with the blade set to a plan angle of 40-45°. During the third pass lengthwise of the trench the spoil is spread with the blade plan angle of 90°. The fourth and fifth passes along the trench edges are performed with a blade plan angle of 40-45°, the sixth pass with a plan angle of 90°. The blade slope angle during the third and sixth passes should be 0°. The seventh and eighth passes are accomplished with a plan angle of 40-45° and a slope angle equal to the assigned camber of the trench.

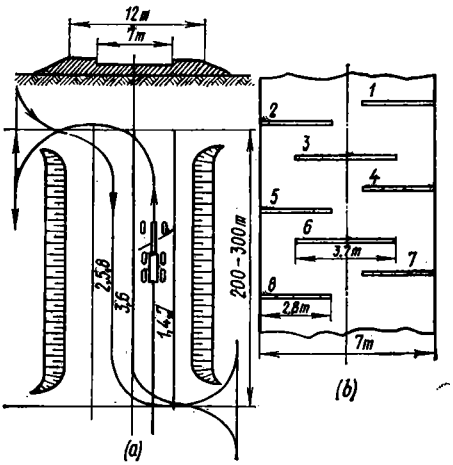


Fig. 12.3. Trench levelling and finishing

(*a*) motor grader movement diagram; (*b*) sequence of passes; *1-8*—numbers of passes

The trench sections to be levelled should not be shorter than 200-300 m.

After levelling the trench, two circular passes are made to level the shoulders. Excessive spoil is removed from the shoulders behind the bank. The blade plan angle is from 50 to 70° and the slope according to the roadbed camber.

12.2. Placement of Pavement Foundations

To impart the required strength to the road pavement, it is placed on a foundation, which is a course taking up a considerable part of the vehicle wheel loads. The foundation, however, does not contact the wheels and is not exposed to the elements that is why it is made of weaker materials than the pavement.

The foundations are constructed from local materials such as gravel (ballast), slag, and sand. The optimal mixtures used for the purpose comprise 25-35% of gravel and ballast balanced by soil.

Gravel and ballast foundations are fairly strong and labour input required for their placement is not too high.

The foundations are laid with ballast or weak rock which is not suitable for pavements, weak limestones, shell rock, gravel, stone and boiler slags, and crushed bricks.

All these foundations are of the bound type and are rolled in the course of placement which allows for passing road-building machines at all stages of construction thus increasing construction rate.

Sandy foundations are also widely used but they are difficult for passing building machines during continuous construction.

Foundation laying comprises the following main operations: delivery and unloading of materials to the trench, levelling and profiling of the materials, consolidation of the foundation layer.

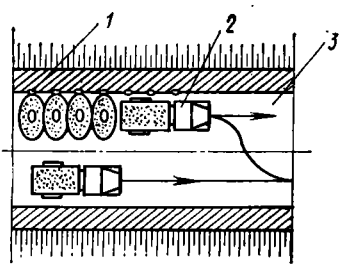


Fig. 12.4. Unloading gravel in trench

1—unloading point; *2*—dump truck; *3*—trench

The foundation materials are brought by dump trucks, scrapers and other transport vehicles and placed in the trench in heaps or windrows over a road section of at least 300 m long. The materials are unloaded at one side or along the center line of the trench but in such a way that the trench be passable. Unloading points are marked with pegs placed on the shoulder near the trench edge (Fig. 12.4).

The foundation materials are levelled and spread in the trench with the use of motor graders. The blade is set to a plan angle of 45°, while the slope angle is determined by the design camber of the foundation. The blade is lifted to a height equal to the design depth of the foundation course. The graders turn at the section ends on specially organized ramps.

Depending on the foundation layer thickness (8 or 12 cm) the materials are moved and levelled in seven or nine passes, respectively. Figure 12.5 illustrates the sequence of grader passes for moving or levelling gravel unloaded in heaps at one side of the trench. During circular passes the grader

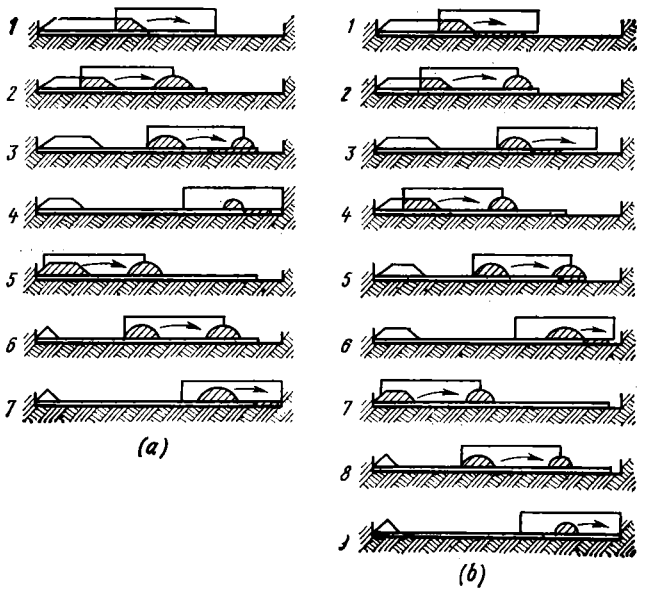


Fig. 12.5. Diagram of distributing gravel in trench
(*a*) 8-cm layer; (*b*) 12-cm layer; *1-9*—motor grader passes

moves and spreads the materials. During a reverse pass the blade should be turned through 90° with respect to the direct one, i.e. right- and left-hand ends of the blade should alternately be engaged. If the materials are unloaded along the center line of the trench, there is no need for changing the plan angle by 90° during a reverse pass.

The materials spread over the trench are profiled at higher grader speeds. The first two passes are started from the trench edge at a plan angle of 60-75° (Fig. 12.6). The third pass is accomplished along the trench center line with a blade plan angle of 90°. Next three similar passes are carried out. The blade slope angle in passes *1*, *2*, *4* and *5* is equal to that for the design camber of the foundation.

When making a sandy foundation for pavements of soil reinforced with binders (bitumen or tar), motor graders spread

sand widthwise of the trench, level soil over the sand layer, mix soil with sand, windrow the mixture, then spread and level it.

Sand for the foundation is brought from pits and borrow cuts and is unloaded in the roadbed trench. Sand is spread and moved over the trench by circular or shuttle passes of the grader with the blade set to a plan angle of 70-80° and lifted to the required sand layer thickness.

Soil for the foundation is brought from side borrow pits by scrapers and is spread over the sand layer by motor graders so that the total height of the layers does not exceed 20 cm. Soil is mixed with sand by the motor grader during 18-20 circular passes. After eight to ten passes the mixture is moved to windrows with a base width of 2.4 m corresponding to the loader or mixer span. The bitumen-and-soil mixture obtained after mixing is spread and levelled along the width of the carriageway by motor graders. To spread the mixture the graders perform from 14 to 16 circular passes starting from the trench axis. The blade plan angle is 45-50°, and the slope corresponds to the roadbed camber. Levelling requires from six to eight passes with a blade plan angle of 80-90°.

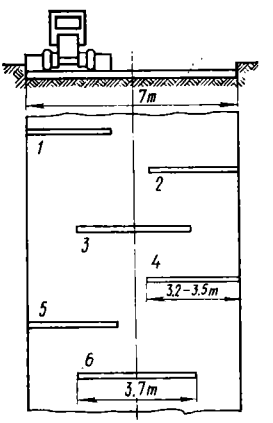


Fig. 12.6. Profiling gravel/ballast material in trench

1-6—motor grader passes

12.3. Mixing Method

To increase stability of the carriageway, preclude bumping and tracking of earth roads, light-duty pavements are provided. The mixing method is carried out with the use of motor graders which spread and mix soil or gravel materials with inorganic (cement) and organic (bitumen, tar) binders and additives many times. Such improved roads offer high-quality and low-cost stable pavements.

Cement-bound pavements may include one or two layers depending on the predicted traffic pressure. Figure 12.7 illustrates an example of a cement-bound pavement structure. A single-layer pavement (Fig. 12.7*a*) is 14-18 cm thick, and is designed for up to 200 five-ton trucks per day. In case of a two-layer pavement (Fig. 12.7*b*), the bottom layer is 12-18 cm thick and the top layer is 12 cm thick. Such a pavement withstands up to 500 trucks per day.

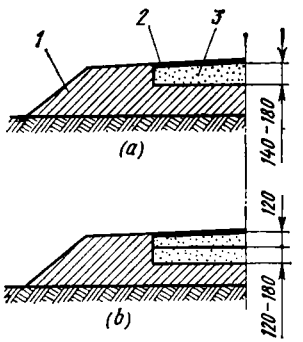


Fig. 12.7. Cement-bound road pavement

(*a*) single-layer; (*b*) double-layer; *1*—roadbed; *2*—surface treatment layer; *3*—cement-bound layer

The cement-bound surface is subject to double treatment with bitumen.

Depending on the road-building equipment used, volume of work and weather conditions, the cement-bound foundations and pavements are constructed by a mechanical plant with a road harrow or soil mixer being a leading machine. When building roads of categories IV and V with relatively small volumes of earthwork, it is expedient to use a mechanical plant with a road harrow as a leading machine. The advantages of road harrows are their relatively low price and flexibility. However, multiple passes are needed to ensure proper mixing of the materials.

Figure 12.8 illustrates work planning for building a single-course cement-bound soil foundation.

Soil is excavated from a borrow pit and is brought onto the roadbed by a pull-type scraper (*1*). A motor grader (*2*) spreads the soil throughout the foundation width in an even layer during six circular passes (the section being 120 m long). The spread soil is crushed by a road harrow (*3*) during four passes lengthwise of the foundation. Lime is brought by a cement truck (*4*) and water by a sprinkling truck (*14*). Cement is injected into the soil by a cement distributor (*5*) during four passes lengthwise of the foundation. Cement is mixed with soil by the road harrow (*13*) during four passes.

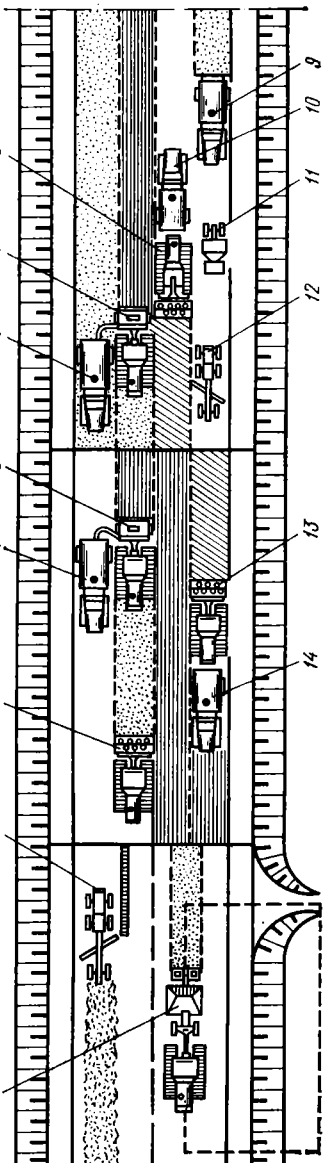


Fig. 12.8. Making foundation of cement-bound soil by mechanical plant with road harrow

1—scraper; *2*, *12*—motor graders; *3*, *8*, *13*—road harrows; *4*, *6*—cement trucks; *5*, *7*—cement distributors; *9*—tar paver; *10*, *14*—sprinkling trucks; *11*—roller

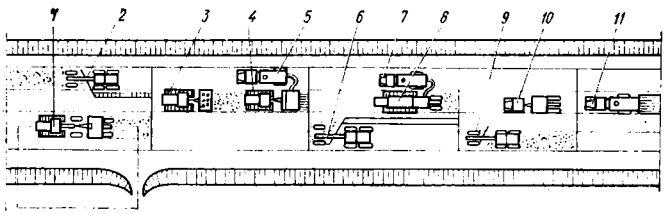


Fig. 12.9. Construction of cement-bound soil foundation by mechanical plant including soil mixer

1—scraper; *2*, *6*, *9*—motor graders; *3*—road harrow; *4*—cement distributor; *5*—cement truck; *7*—sprinkling machine; *8*—soil mixer; *10*—roll; *11*—tar paver

Cement is brought by a cement truck (*6*) and water by a sprinkling truck (*10*). Cement is injected into soil by a cement distributor (*7*) during four passes. Soil is mixed with cement by the road harrow (*8*). The mixture is levelled and profiled by a motor grader (*12*) during 18 circular passes. The bound-soil layer is consolidated by a roller (*11*) during 18 passes. Hot bitumen is delivered by a tar paver (*9*) and is spread over the finished foundation by the motor grader.

When building roads of highest categories, it is advisable to use a mechanical plant with a soil mixer (Fig. 12.9) which uniformly and finely divides soil lumps, moistens and mixes soil with binders and introduces additives to obtain a homogeneous mixture during one pass.

Soil of group II is excavated and brought to the roadbed through an average distance of up to 200 m by a pull-type scraper (*1*). The motor grader (*2*) spreads the soil throughout the foundation width during six circular passes at a speed of 3-4 km/h over a section 120 m long. A road harrow (*3*) mixes and crushes soil during one pass following in the tracks (four passes to cover the entire foundation width). A cement truck (*5*) brings cement (10% of the mixture weight), and a distributor injects it into the soil during four passes lengthwise of the foundation.

The motor grader (*6*) windrows the soil mixture during six circular passes. The soil mixture is mixed with cement and is simultaneously moistened by a soil mixer (*8*) whose tank is filled with water from a sprinkling machine (*7*). Then the ground mixture is spread and profiled by the motor grader

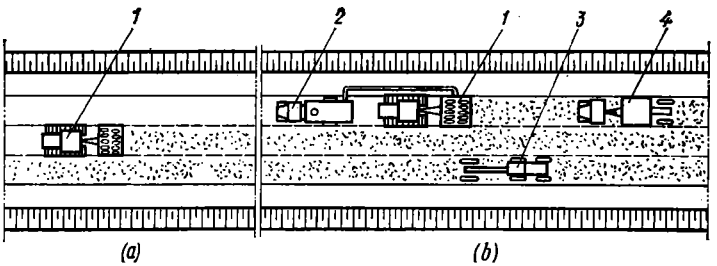


Fig. 12.10. Construction of foundation with liquid binders by mechanical plant including road harrow

(*a*) soil crushing; (*b*) distribution of soil and mixing with binders; *1*—road harrow; *2*—bitumen truck; *3*—motor grader; *4*—roller

(*9*) during 14 circular passes and is compacted with a roller (*10*). Liquid bitumen delivered by a tar paver (*11*) is spread over the finished foundation.

In *strengthening soil with organic binding materials* use is also made of a mechanical plant wherein a road harrow or a soil mixer are leading ones.

Figure 12.10 illustrates operation of a mechanical plant with a road harrow as a leading machine during soil treatment with liquid binders. The roadbed is levelled with a motor grader. If surface irregularities are considerable, the top layer is scarified and rolled. When using soil from borrow pits it is brought by a scraper, mixed with in-situ soil and is spread over the prepared surface by a motor grader during 8-12 circular passes. A road harrow (*1*) crushes soil layer 18-20 cm thick during two-four passes following in the tracks (particles larger than 5 mm should not exceed 25% of the overall soil volume). To maintain the required moisture content, soil is sprinkled with water 2 or 3 h before the work.

Liquid binders fed from a bitumen truck (*2*) via a hose are injected into soil by a proportioning distributor of the road harrow. The binders are proportioned with a simultaneous mixing and distributed in soil during one or two passes of the harrow following in the tracks. Soil is additionally moistened and water-soluble chemical additives are introduced into it. Crushed soil is mixed with binders and chemicals during two or three passes of the road harrow at a speed of

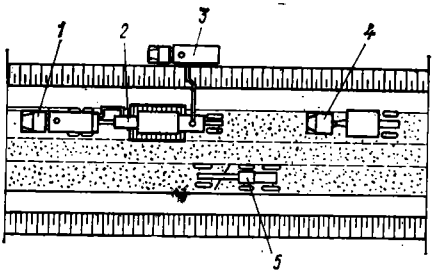


Fig. 12.11. Construction of foundation with liquid binders by mechanical plant with soil mixer

1—bitumen truck; *2*—soil mixer; *3*—tanker with water; *4*—roller; *5*—motor grader

0.5 km/h. The treated layer is consolidated with a pneumatic tire roller (*4*). The top layer is made over the consolidated surface by a double treatment of the latter with a bitumen emulsion or other film-forming liquid.

The sequence of operations for treating soil with binders by a mechanical plant with a soil mixer is shown in Fig. 12.11. Operations for levelling the roadbed surface, spreading spoil and mixing it with in-situ soil are carried out as in the previous process.

Soil is crushed and mixed with additives, binder is proportioned and distributed, soil is mixed with binders and moistened additionally by a one-pass soil mixer (*2*). The thickness of the layer being treated is up to 25 cm. Binders are fed to the soil mixer from a bitumen truck (*1*). The operating speed of the machine depends on the treated layer thickness and soil group and is 0.1-0.15 km/h for loam and 0.25-0.5 km/h for loamy sand.

The layer is consolidated with a roller (*4*) while the camber and gradient are restored by a motor grader (*5*) throughout the road foundation width over the section length.

Building pavements of gravel or ballast treated with bitumen or tar comprises cleaning the foundations of dust or litter, spreading gravel over the roadbed, mixing gravel with binders (Fig. 12.12), levelling and finishing the roadbed.

Material is brought onto the roadbed and arranged in heaps along the road center line. Next the material is brought into a continuous windrow of uniform cross section by a

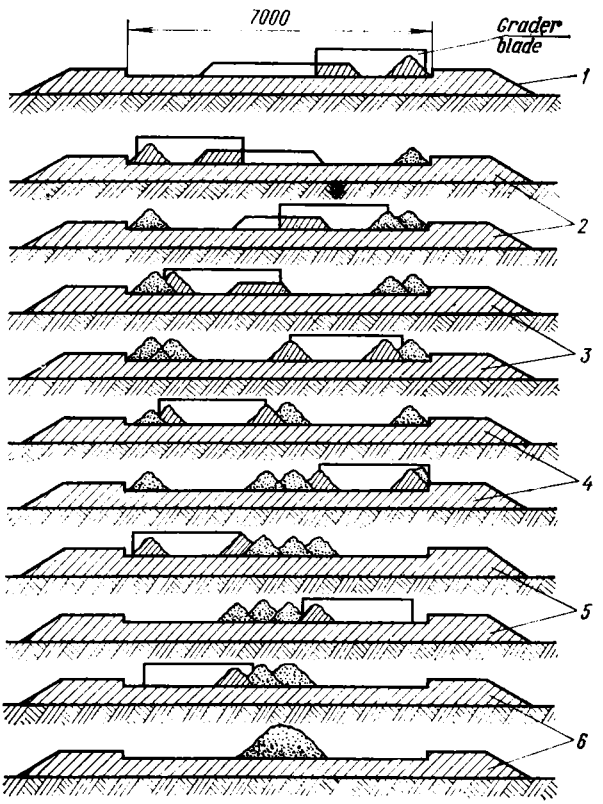


Fig. 12.12. Mixing of gravel with binders
1-6—number of passes

motor grader during one or two passes. Lifting the blade to a height of 20-25 cm and setting it to a plan angle of 90°, the windrow is reformed into a flat-top windrow up to 20-25 cm high and 3.6 m wide.

The tar paver spreads binders over the gravel flat-top windrow which are then mixed by three or four passes of the grader. After each mixing the mixture is again gathered into a windrow along the road center line, the windrow is again reformed into a flat-top one and the operation is repeated.

Materials are mixed by the motor grader during three or four circular passes by moving the mixture from the road center line to the trench edge to both sides and back. The blade is set to a plan angle of 45°, pitch of 50-60° and slope corresponding to the road camber.

After distributing the specified amount of binders, the materials are finally mixed till a homogeneous mixture is obtained. The improved pavement is completed by distributing the homogeneous mixture over the trench, profiling and consolidating the carriageway.

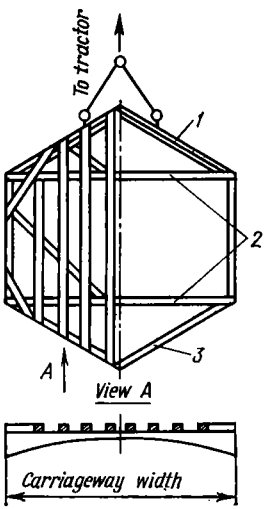


Fig. 12.13. Ironing template

The mixture is spread and profiled by a motor grader during four-five passes. During the first pass with a blade plan angle of 85° the top part of the windrow gathered along the road center line is moved to both sides to about a half of its height. During next two circular passes the material is uniformly moved to both sides off the center line. The blade is set to a plan angle of 45-50°. During the fourth pass the blade is set to the required pavement depth making allowance for subsequent consolidation to a slope corresponding to the specified camber and to a plan angle of 60-65°. The material is levelled while moving from the edges towards the center line. The last pass is used to smooth the carriageway middle.

To smooth the surface and ensure the required camber throughout the carriageway length, an ironing template (Fig. 12.13) is attached to the motor grader during the last pass. The ironing template is a wooden structure made from beams lined with steel. It includes four templates. A front template (*1*) is intended to cut off bumps and move the mixture to the edges of the carriageway by means of the angled beams. Two middle templates (*2*) are made as beams following the carriageway camber and are intended to smooth

out longitudinal irregularities. A rear template (*3*) has a V-shape in plan to gather mixture overflown through the middle templates and move it to the road center line.

The ironing template ensures a high quality of pavement surface and the required camber of the road. It obviates the need for manual patching which is indispensable when finishing operations are carried out by the grader blade.

Mixing various materials with binders by a grader blade which is the main working implement of the machine is low productive since it requires a great number of passes. Besides, prolonged mixing deteriorates the mixture quality.

To speed up the mixing process, use is made of a plough mixer (Fig. 12.14) installed on the grader draft frame instead of the circle. The mixer is lifted and lowered by the blade control mechanisms. It consists of a plough (*1*) and two wings (*2*) arranged at 38° to the longitudinal axis.

The procedure for mixing materials with a plough mixer is as follows. A windrow laid along the road center line is reformed into a flat-top windrow by a motor grader with a lifted mixer. After binders are sprinkled, the materials are mixed. The motor grader moves along the windrow so that the mixer penetrates the latter to shift the material to both sides from the plough to the wings. Owing to their angular position, the wings again gather material at the center line thus making the original flat-top windrow. Such opposite currents and tipping over of the material result in vigorous mixing. The plough mixers double the machine productivity and improve quality of mixing.

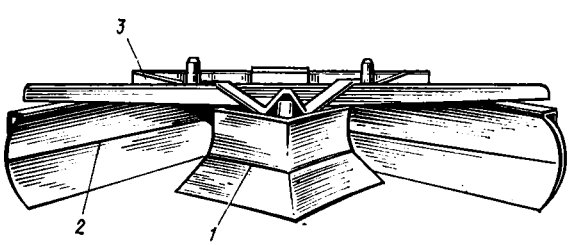


Fig. 12.14. Plough mixer
1—plough; *2*—wing; *3*—frame

Chapter 13

ROAD MAINTENANCE AND REPAIR

13.1. Principal Maintenance and Repair Operations

Upon completion of construction the motor road is transferred to the road maintenance service.

Traffic loads, temperature fluctuations, falls, etc. cause wear and damage to motor roads. For instance, bitumen-based pavements are heated by the sun light to 60-70°C, and become soft so that waviness and folding result. Abrupt drops of temperature lead to cracking of such pavements. Gravel pavements built without binders dry out in hot weather and get loose.

The principal defects of earth, gravel and ballast roads are pot holes, tracks, waviness and surface wear. Pot holes result from shearing of pavement with a weak foundation under the action of considerable wheel loads. Tracks appear when vehicles are moving following in the tracks; waviness, which is a number of folds on the surface, stem from surface shift during braking. Surface wear is mainly caused by knocking out of gravel or ballast particles from the pavement layer.

The object of the road maintenance service is to maintain and repair roads.

Road maintenance comprises operations necessary to maintain the pavement and roadbed clean and in good repair for year-round operation. These systematic operations include surface cleaning with brushes and sprinkling machines, snow ploughing, ice control, care of heaving sections and water drain facilities, grading of shoulders and slopes.

All roads are subject to period repairs. Depending on the nature and amount of work, the repair operations are divided into patching, repair and renewal.

Patching is eliminating small surface defects and restoring isolated areas of the road.

Repair is periodic restoration or mending of pavements on separate sections of the road.

Renewal is remaking of a considerable portion or the entire road with rebuilding the pavement, widening the carriageway, etc.

The type of road maintenance depends on the season and weather.

Summer operations consist mainly in keeping the carriageway clean and in good order and maintaining the roadbed. In autumn when falls are heavy, the road should be also cleaned of mud. Winter operations are mainly snow ploughing and ice control to ensure safety of traffic. In spring it becomes necessary to restore water drainage, remove snow and mud from the carriageway, take measures to preclude heaving, the latter being a most important spring work. Heaving results from accumulation of moisture which occurs in roadbed upper layers in winter. During spring thawing, water collected under the pavement oversaturates the foundation soil and is forced out by the vehicle wheels through cracks and pot holes formed under the action of traffic loads. This does great damage to the pavement, such as settlements and pot holes, i.e. heaving. The beginning of heaving is indicated by the advent of damp stains on the pavement surface and by cracking.

To preclude or weaken the action of heaves, the following operations should be carried out at the heaving sections.

At the beginning of thawing, all snow and ice should be removed from the pavement, shoulders and inner slopes of the side ditches. After snow cover moves off, dig lateral air funnels, 25 cm wide, reaching the trench bottom in every 3 or 4 m in the shoulders of a weak pavement lengths. Drain water formed during soil thawing through these funnels. Another way is to cut a small trench, 25-30 cm wide by a motor grader along the shoulder 10-15 cm away from the pavement edge and dig lateral drains from the trench in 50-80 m. As shoulder soil thaws, the trenches are deepened by longitudinal passes of the grader.

If heaving persists, the damaged area should be protected against direct action of wheels and soil thawing should be slowed down. To this end, a sand bed up to 15 cm deep is laid over the heaving area and board panels or brushwood mats are placed on top. The panels or mats are covered with another layer of bed up to 10 cm deep. Traffic is not stopped in this case. If heaving is intense, traffic is temporarily prohibited for the period of repair and special bypasses are constructed. After soil thaws and dries out completely, the air

funnels and trenches are filled and the defects are patched.

Motor graders are extensively used substantially in all road maintenance operations.

Roadbed maintenance includes levelling, cutting and filling of shoulders, cleaning of side ditches, drains, reinforcement of fill and cut slopes and other elements of the roadbed.

When shoulders depress near the pavement edges, soil is moved by the grader towards the pavement, and if the shoulders elevate (e.g. when the pavement depresses), soil is cut and moved to the roadbed edge and is then removed by loaders and vehicles.

To restore a depressed shoulder, deep track or a pot hole, it is filled with soil brought from a pit and profiled by the grader blade. The mended shoulders are reinforced with gravel, sand and slag. Material is laid on the shoulders in small heaps which are spread and smoothed out by the graders.

Maintenance of ditches, and drains consists in cleaning them of litter and drift. These operations are accomplished by a motor grader equipped with a back sloper and ditch cleaner. Spoil removed in cleaning and deepening of the ditches is spread by the graders over the edges.

Maintenance of improved earth roads with pavements reinforced by sand, gravel and ballast consists of smoothing and profiling the roadbed and improving the pavement by various additions and binders.

In renewal and patching of improved roads, the motor graders scarify the old pavement, smooth out the additions, mix materials and profile the surface.

Scarifying of the old pavement is needed to allow subsequent restoration of the roadbed with a grader blade. This operation is carried out in main operating gear with a constant penetration of the scarifier teeth. If the teeth do not penetrate into the layer at the beginning of scarifying, the number of teeth should be decreased to three or one.

To preclude abrupt loading of the engine and transmission and breakage of the scarifier, the operation should always be started from rest. Besides, to prevent bending of the scarifier teeth, scarifying should be carried out only during forward movement. The maximum scarifying depth for a heavy grader is 250 mm at a scarifying angle of 40°. The blade should be lifted during scarifying.

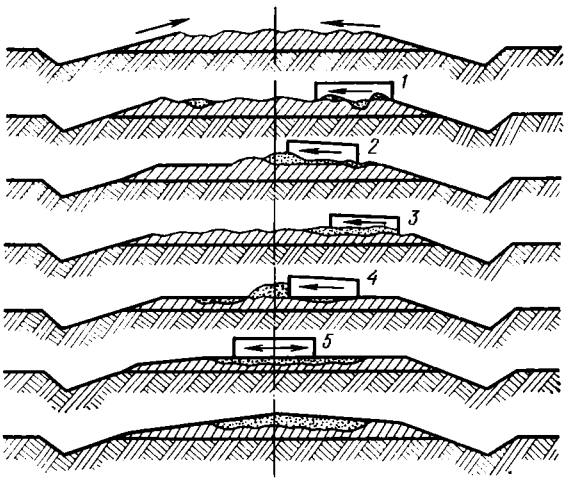


Fig. 13.1. Restoration of road profile
1-5—motor grader passes

Restoration of the roadbed is one of the principal operations in repair of earth roads.

If surface damage is not excessive and there are some tracks and pot holes, the roads are restored as follows. Bumps are cut and then gravel or ballast is filled and spread.

According to another method, soil is cut along the roadbed shoulders (Fig. 13.1) and then is moved towards the road center line by two or three circular passes of the grader. The blade is set to a plan angle of 40-45° and slope angle of up to 11°. The soil is smoothed over the carriageway by final passes. All irregularities, tracks and pot holes are filled, bumps are cut and the roadbed is profiled by the blade to ensure the required camber. If the amount of soil cut from the shoulders is insufficient to restore the profile, the borrow pits are widened or additional material is brought.

Prior to improving earth roads with additions, the roadbed surface is levelled, the tracks and pot holes are filled, and soil is scarified to the depth of the course to be improved. Additions are laid on the scarified surface in the form of a windrow, spread throughout the roadbed width by four or

five grader passes and mixed with scarified soil of the roadbed.

The mixture is finally prepared to become homogeneous in consistency and color by the motor grader. To this end soil is windrowed and spread over the roadbed and then light rollers consolidate the fill.

Improving earth roads by mixing with binders can be performed with introducing additions to decrease consumption of binders. The work begins with smoothing the road surface by grader passes with cutting a soil layer for mixing with binders. The spoil is windrowed and additions are heaped nearby. Soil is mixed with additions during grader passes and is spread over the roadbed. Then liquid bitumen or tar is poured from a tar paver and the soil is mixed with binders by successive passes of the grader. In so doing the mixture is first moved to the road center line and then to the edges. The blade is set to the full depth of the layer and a plan angle of 45°. The road is finally profiled by the grader and is then consolidated with rollers.

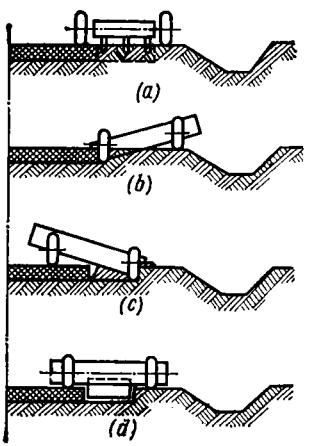


Fig. 13.2. Widening of carriageway

(*a*) shoulder scarifying; (*b*, *c*) shoulder cutting; (*d*) cleaning of widening strip

Maintenance and repair of gravel pavements include the same operations as those of earth roads.

Worn gravel pavements are repaired by profiling the road with adding gravel which is brought to the shoulders in the form of windrows. The pavement is cleaned of mud and scarified to the required depth. The spoil is gathered by the grader into a sized windrow and the foundation surface is levelled. Then gravel from the shoulder is shifted and spread by graders over the carriageway.

Next, liquid bitumen or tar is poured and mixed with gravel by the grader. The pavement is profiled by the grader and consolidated by rollers.

Repair work also includes widening of the carriageway which is usually done to cope with increasing traffic and to improve the road category. The road width is increased mainly at the expense of the shoulders on one or both sides. The widening value is from 0.5 to 1.75 m per side.

The work starts with scarifying the pavement layer by a scarifier (Fig. 13.2*a*). Scarifying is accomplished in several passes, then the scarifier is lifted and the blade is engaged.

The first cut (Fig. 13.2*b*, *c*) with the blade shifted rightward is made with the left-hand end on the side of the trench inner edge. Cutting is continued at both shoulders by two or three circular passes till the design depth of the trench is reached. Then the blade is reversed and the trench outer edge is cut with the right-hand end of the blade down to the required depth. The blade plan angle for this operation is 35-40°.

Finally, the widened trench bottom is cleaned and levelled (Fig. 13.2*d*). To this end, a cover plate protruding under the blade and extending throughout the trench width is attached to the blade. The blade is set to a plan angle of 90° and a slope angle corresponding to the trench bottom camber.

The spoil from the trench is removed from the carriageway and shoulders or used for filling in smoothing out of the roadbed.

13.2. Winter Maintenance

Winter maintenance presents special problems. In long winters, heavy snow falls, storms and glazing hinder uninterrupted and safe traffic. For instance, friable snow cover up to 10 cm thick drastically decreases the speed of conventional motor vehicles, while when such a cover reaches 45-50 cm, the road becomes impassable. With a concrete snow, vehicles make tracks and pot holes which considerably impede traffic. Ice crust on the carriageway also impairs road conditions reducing safety speed limit and affecting traffic safety.

To provide for troublefree and safe traffic in winter, the road maintenance service should ensure that the following conditions are met:

— no snow cover is formed on improved roads;

— a layer of concrete snow up to 8-10 cm thick is allowed on roads with intermediate or light-duty pavements.

The roadbed should be clear of snow throughout its width and the road surface should not be slippery.

Despite various snow protection facilities now in use, snow cover is formed on the road as a result of passage of snow and snow falls (Fig. 13.3). Therefore, the carriageway has to be periodically cleaned of snow. This is accomplished by truck- and tractor-mounted snow ploughs and throwers and by motor graders.

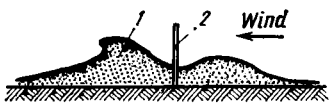


Fig. 13.3. Formation of snow bank

1—snow bank; *2*—line of boards

The principal winter maintenance operations are patrol cleaning of snow brought by snow falls or wind, clearing of snow blockades, removal and spreading of snow windrows left by snow cleaners, removal of ice crust from the carriageway, cleaning of side ditches of snow.

Using motor graders for cleaning roads and areas of snow widens the sphere of application of these machines and eliminates their winter idling. On the other hand, motor graders provide for year-round operation of roads.

When cleaning roads with motor graders, use is made both of the main blade and mounted implements such as two- and one-mouldboard snow plough, extension, and ditch cleaner.

A medium and heavy grader can blade clog snow up to 25 cm thick (Fig. 13.4*a*). With a thicker snow cover, the blade efficiency decreases since great amount of snow passes over the blade top (Fig. 13.4*b*). Snow increases skidding of the grader rear wheels and impedes operation since the machine starts hunting.

The maximum thickness of a clog snow layer that can be cleaned by the grader blade is 40 cm. Regular cleaning of the carriageway starting with the first snow fall or storm when layer thickness reaches 5-10 cm and more is called patrol cleaning. This operation is carried out by truck-mounted snow cleaners with driven brushes and by motor graders. To clean the carriageway effectively and throw snow through a

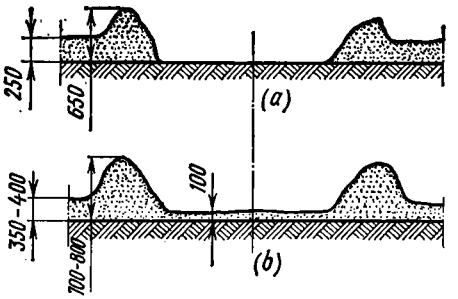


Fig. 13.4. One-pass blading of snow
(*a*) with cover up to 25 cm thick; (*b*) with cover more than 25 cm thick

sufficient distance, patrol cleaning is accomplished at high speeds, (20-30 km/h). Using the motor grader blades for patrol cleaning is advisable when a clog snow layer is 20-40 cm thick.

The number of grader passes necessary to clean the road of snow depends on the roadbed width. The roadbed up to 7 m wide can be cleaned in two or three passes starting from the center line. If the width exceeds 7 m, the passes are started from the road edges and snow is moved towards the side ditches (Fig. 13.5). During subsequent passes the snow is shifted from the road center line to the clean lane and then again to the side ditches. About three circular passes are needed to clean a roadbed up to 9 m wide. The plan angle of the blade is 40-50°, the slope angle is 3°.

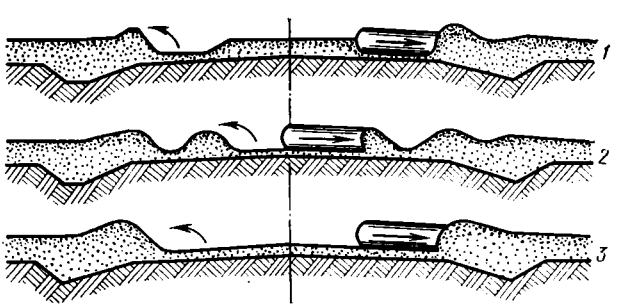


Fig. 13.5. Snow ploughing
1-3—motor grader passes

To clean areas of friable snow the motor grader should perform circular passes approaching the center. The blade is set to a plan angle of 50-60°. An extension (wing) is mounted on the free end of the blade to throw snow through longer distances. Besides, to increase productivity of the machine the blade is equipped with a widening piece. The snow engaged during the first pass is windrowed outside the area. The cutting and windrowing are continued till the area is cleaned completely.

Snow moved aside to the shoulders during patrol cleaning piles up and forms banks so that the carriageway takes the form of a shallow cutting exposed to snow drift. Therefore, snow banks at the shoulders should be removed or spread out which can advantageously be accomplished with the aid of motor graders. Banks up to 40 cm high are removed from the shoulder outside the roadbed at a grader speed of up to 15 km/h.

Snow banks more than 40 cm high can be removed by two methods: by blading or by cutting with moving towards the carriageway. In the first case, the blade is sideshifted as far as possible and set to a plan angle of about 50°. The grader moves at a speed of 20-30 km/h whereat wheel traction force is sufficient to remove snow bank up to 50 cm high from the shoulder and throw it through 5 m. To increase grader productivity the blade can be provided with an extension up to 1.5 m long.

Snow banks higher than 1 m are removed from the shoulders by cutting and moving to the carriageway. The blade is sideshifted and set to a plan angle of up to 80° and slope angle over 50° so that its lower end touches the edge of the clean shoulder. The operating speed of the grader should be about 10 km/h. In two or three passes, the bank slope becomes 1:2.5 streamlining the road profile. Snow piled on the carriageway is thrown outside the roadbed by snow throwers.

To remove snow from the bank located over the side ditch and clean the inner slopes, the blade is set to a plan angle of 45-50°, a pitch angle of 60-70° and a slope angle of 18-20°.

To clean the side ditches of snow, a ditch cleaner following the ditch cross section is mounted on the blade. The blade is shifted aside and is set to a plan angle of 60-70° and zero

slope angle. Two or three passes are needed to clean the ditch.

If patrol service is not regular, snow on the carriageway consolidates while alternating thaws and frosts convert it into ice crust. To remove such a crust from the carriageway, the grader blade is equipped with a toothed cutting edge (Fig. 13.6). Toothed cutting edges up to 18 mm thick are manufactured from hard steels while the tooth points are made of wear-resistant alloys. Replacing regular cutting edges with the toothed ones takes up to one hour.

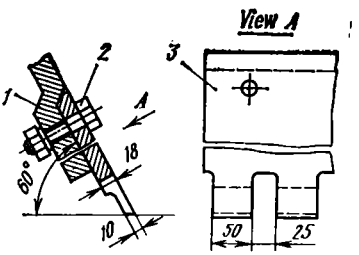


Fig. 13.6. Toothed cutting edge
1—blade; *2*—edge attachment; *3*—cutting edge

When cleaning the road of heavily glazed snow, the pitch angle of the toothed cutting edge blade should be 30-40° and the plan angle up to 65°. With a weaker snow cover the plan angle is 65-75° and the pitch angle is up to 60°. Ice crust up to 3-4 cm thick is chipped with a plan angle of up to 90°. As the blade is filled with chipped ice, it should be periodically moved aside. Grooves left on the surface by the toothed cutting edge are easily removed by the regular cutting edge.

Optimal operating speeds for cleaning the road of ice crust or a top layer of concrete snow is 6-10 km/h. Such a speed allows operation without excessive skidding at a sufficiently constant plan angle and penetration of the grader blade.

Mounted one- and two-mouldboard snow ploughs arranged in the front part of the grader improve the efficiency of its winter use for maintaining roads and areas. A snow layer up to 60 cm thick can be removed by the grader equipped with a snow plough.

The motor graders with snow ploughs are employed for patrol cleaning. This operation is carried out at maximum possible speeds of 15-20 km/h. It is most advisable to use motor graders for the purpose when the snow cover thickness is 20-40 cm.

Motor graders with double-mouldboard snow ploughs make the first pass along the road center line moving snow to

the edges. In case of a single-mouldboard ploughs, the pass is started from the road edge. Such snow ploughs are used on sections with shallow snow covers where single-sided cleaning is needed.

If snow covers reach 40 cm, it is expedient to use motor graders equipped with both double- and single-mouldboard snow ploughs. The grader with a double-mouldboard plough moves along the road center line shifting snow to both edges while the single-mouldboard plough grader moves snow to the edge by circular passes.

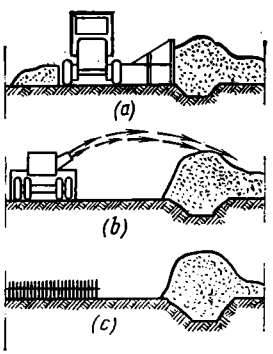


Fig. 13.7. Snow cleaning by mechanical plant

Motor graders are also used as auxiliary machines in mechanical plants including snow throwers and truck snow cleaners with driven brush.

The mechanical plant cleans the shoulders, cuts snow bank over the side ditch and cleans the latter of snow (an example of operation of such a unit is shown in Fig. 13.7). During the first pass of the grader along the right-hand shoulder, snow caught by the blade is moved to the carriageway (Fig. 13.7*a*). The blade is equipped with a widening piece to prevent overflow of snow. The blade is set to a plan angle of 50-60°, a pitch angle of 45° and a slope angle of 2-3° towards the side ditch. The grader speed is from 5 to 6 km/h.

A snow thrower which follows the grader along the right-hand shoulder removes snow from the carriageway (Fig. 13.7*b*). A snow plough truck with a driven brush performs final cleaning of the carriageway (Fig. 13.7*c*). The left-hand shoulder is cleaned while the unit is moving in the opposite direction.

Part Three

Operation and Maintenance of Motor Graders

Chapter 14

SCHEDULED PREVENTIVE MAINTENANCE AND REPAIR OF MOTOR GRADERS

14.1. Machine Reliability

Separate parts are subject to troubles and damage in the course of grader operation. These troubles and defects are determined by the following design, production and operation factors.

Design factors cause troubles as a result of erroneous dimensioning or improper selection of materials failing to withstand effective stresses, incorrect choice of fits and tolerances, thermal treatment type, etc.

These troubles are eliminated while testing new types of graders and optimizing their series production.

Production factors dictate troubles stemming from violation of manufacturing processes and latent defects.

Operation factors lead to defects primarily because of incorrect operation of the grader, overloading and the operator's errors. Operation troubles may often stem from low-quality servicing, adjustment and failure to detect production and design defects in due time. The most frequent defect is wear of mating parts. Wear manifests itself in degrading of surface finish, geometry and dimensions of the parts. As a result, impermissible gaps violating normal operation of the parts appear at mating points.

Wear results from friction of mating parts. *Friction* is resistance to relative displacement of mating bodies which develops at the point of their contact. Depending on the nature of relative displacement of contact surfaces, sliding and rolling frictions are distinguished.

Sliding friction is rubbing of one body against another whereat their speeds at the point of contact are different in magnitude or direction or both.

Rolling friction is rubbing of one body against another

characterized in that their speeds at the point of contact are similar in magnitude and direction.

Depending on the presence or absence of lubricant in the zone of contact of two rubbing bodies, friction is divided into two types: unlubricated (dry) friction and lubricated friction.

When the amount of lubricant is insufficient or its quality is low, separate portions of rubbing parts come into contact which causes wear.

Since in-service wear of a machine cannot be avoided, it is vital to determine the degree of part wear and need for repair. Initial wear stems from run-in of two parts. Such wear is insignificant and depends on clearances and surface finish. Then wear increases over prolonged period of operation to reach finally the value whereat part mating is considerably violated. To denote the degree of wear, engineers use the terms permissible wear and limit wear.

Permissible wear is the condition of mating parts whereat one of them or both can function normally till next repair. *Limit wear* is such a state whereat further operation may lead to part breakage.

The most common methods of determining part wear are visual inspection, micrometric measurements, and determining metal particles in oil. Visual inspection provides for detecting wear visible to the naked eye. These are cracks, deformation, disintegration of welds, corrosion, etc. The method of micrometric measurements consists in checking part dimensions after a certain period of operation and comparing them with the original ones.

Part wear products are minute metal particles suspended in oil lubricating the parts. When sampling such oil, part wear can be estimated by the presence of metal particles in it.

Thus, in the course of service a motor grader can be in the operable or inoperable state, i.e. capable of performing its functions or not, which may stem from different reasons.

The ability of a machine to perform the designed functions with its operation characteristics being preserved within a definite period of time is called *reliability.*

Machine reliability is a most important technical-and-economic characteristic of its work. A non-reliable machine

with frequent dead periods caused by failures cannot be used to the advantage despite its valuable properties such as high productivity and comfortable conditions for the operator.

Machine reliability is characterized primarily by no-failure operation and longevity.

No-failure operation is the ability of a machine to preserve its serviceability within the designed operating time without failures. Meant by operating time is the duration or amount of work in hours, kilometres, or cubic metres.

No-failure operation is characterized by the mean-time between failures (MTBF), i.e. the ratio of the operating time to the average number of failures occurred during this time.

Longevity is the ability of a machine to remain operable up to the so-called final condition after which it cannot be operated for considerations of safety, drop of efficiency below a permissible level, etc.

Longevity is characterized by the time-between-overhauls (TBO) or service life. Time-between-overhauls is the actual operating period of a new or overhauled machine since the beginning of operation till the final condition. Contrary to the TBO, service life is a calendar duration of machine operation during the same period less idle time.

Machine reliability is also characterized by its *repairability*, i.e. by the possibility of preventing troubles and detecting their causes and eliminating them by maintenance and repair.

Repairability is estimated by the labour input for maintenance and repair, mean time of restoration, and maintenance mean total cost.

On the whole in-service reliability of a machine is evaluated by combined indices—availability and utilization factors which are generally determined as a ratio of machine operation time including the operation time and idle time for maintenance and repairs.

To improve reliability of machines, a set of measures are to be taken in production and operation.

As regards production these measures include modifying the construction, selecting stronger materials and increasing their wear resistance, improving surface accuracy and finish. In-service reliability is greatly dependent upon the operator.

Therefore, the measures here include improving servicing personnel skill, strictly adhering to the manufacturer's operating instructions, observing shipment and storage rules, upgrading maintenance and repair, implementing advanced diagnostic methods.

A skilled operator will rapidly detect and eliminate troubles, perform more accurate adjustments, preclude overload of the machine which may cause failures and even accidents.

A well-organized service involving scheduled high-quality maintenance, diagnostics, uninterrupted supply of spares and materials also provides for improving no-failure operation and longevity of the machine.

14.2. Scheduled Preventive Maintenance

Scheduled preventive maintenance system of construction machines involves accomplishment of maintenance and repair operations for each machine after expiration of a certain time period according to a schedule. Such a schedule makes it possible to prepare the required materials and spares, to plan necessary equipment and personnel. The system is called preventive since its goal is to prevent troubles and eliminate their causes.

The basic objective of the scheduled preventive maintenance system is to ensure operability and good repair of a machine throughout its service life.

Types and terms of maintenance. Maintenance operations per se play an important role in the system. These operations include external servicing (inspection, washing, and cleaning), attachment operations, adjustments and checks, troubleshooting, lubrication and filling.

As regards terms and volumes of work, motor grader maintenance is subdivided into the following: daily or shift maintenance (DM) accomplished before, during or after the working day or shift; scheduled maintenance (SM) performed in definite operating time periods; seasonal maintenance carried out twice a year while the machine is prepared for winter or summer operation. The terms of maintenance rounds are indicated in the grader operating instructions.

The following scheduled maintenance rounds are established for light and medium motor graders: shift maintenance, first maintenance after every 60 engine hours; second maintenance after every 240 engine hours, and third maintenance after every 960 engine hours.

In case of heavy graders, the maintenance rounds are as follows: shift maintenance, first maintenance after 100 engine hours, second maintenance after 500 engine hours, and third maintenance after 1 000 engine hours.

Types of repair. The purpose of repair is to eliminate defects encountered in operation of the machine and to restore its operability.

The motor grader repair operations include cleaning and washing of the machine, disassembly, compiling of list of defects, replacement of worn-out parts with new or repaired ones, assembly and bench tests of the transmission, assembly and running test of the machine on the whole and painting. They also include part restoration work such as welding, plating, fitting and machining operations. The volume of repair work depends on the grader condition and the number of accumulated operation hours. There are two types of repair: routine repair and major repair.

In *routine repair*, the grader is subjected to partial disassembly, its defects are eliminated and separate parts and assemblies are replaced with new or repaired ones. The engine is partially disassembled to replace high-mortality parts and remove carbon deposit and scale; the fuel equipment, hydraulic and electrical systems and transmission are adjusted; and the clutch disks are replaced. Whenever necessary, structural parts and cowlings are welded.

Major repair involves complete disassembly of the grader, restoration of all the mechanisms according to repair specifications, and replacement of worn-out parts with new or repaired ones. The overhauled grader is thoroughly tested.

The terms of routine and major repairs are determined by the manufacturer's documents.

Motor graders can be repaired by the individual, unit and flow methods.

When the *individual method* is used, disassembly, restoration and assembly are accomplished by one team. Assemblies and parts removed from the grader are not mixed but repaired

and mounted back on the machine. This extends the grader dead time. The individual method is employed when the number of machines to be repaired is small, for instance in local shops.

In *unit repair*, the assemblies to be repaired are removed from the machine and replaced by the new or repaired ones. The unit method is advantageous in that machines can be repaired both in service and at repair shops and dead time is considerably decreased.

The repair stock is formed from both the assemblies supplied by the machine manufacturers and the repaired components.

In *flow repair*, the machine is stripped into assemblies and parts (indiscriminate) which are sorted, restored and fed (also indiscriminate) to the assembly station. This type of repair is most advantageous but can be used only if a great number of similar machines is to be repaired.

The operation system includes a number of modern plants capable of performing major repairs.

Maintenance facilities. The fleet of road-building machines including motor graders is concentrated in specialized trusts, departments and mechanized groups. This allows establishment of centralized bases for maintenance and servicing of machines by specialized teams with the participation of machine operators.

Shift maintenance is usually accomplished by the grader operator. It is recommended to perform SM before and after the work.

If a great number of machines is concentrated at one place, special maintenance teams are organized to carry out shift maintenance (including machine fuelling) and scheduled maintenance with the participation of operators. In case of motor graders which return to the base after the shift or are parked within a range of up to 20 km, it is advisable to perform maintenance by such teams at specialized shops. The machines parked at the construction site are serviced by mobile teams.

The field maintenance and repair are accomplished by mobile truck-mounted shops with a minimum set of equipment, tools and spares. Such mobile shops are equipped with an AC generator, crane, winch, welding set and a hydraulic press.

The bases have fuel and oil servicing trucks and vehicles. Routine repairs are usually carried out both in situ (at the construction site) and at the bases, while major repairs are accomplished as a rule at specialized repair plants.

Chapter 15

PREPARATION FOR OPERATION AND MAINTENANCE OF MOTOR GRADERS

15.1. Acceptance, Running-in and Shipment of Motor Graders

Acceptance. New or overhauled motor graders should be subject to acceptance tests before putting them into operation. The acceptance procedure includes checks of technical documents for completeness, external inspection, checks of delivery set, depreservation and trial run of the machine.

External inspection is aimed at determining condition of grader assemblies and parts, quality of preservation and presence of seals specified in the operating instructions.

The delivery set is checked against the list in section "Delivery List" of the service log attached to the machine.

To carry out depreservation, it is necessary to remove covers, scrape off preservation compound by wooden scrapers, wash the cleaned places with diesel fuel and wipe dry with rags, remove packing from all breathers, install headlamps, turn indicator lights and other components removed for railway shipment and connect wires to instruments. Next, lubricant level in gearboxes and coolant and oil levels in cooling and oil systems should be checked and appropriate materials added if necessary.

Then the motor grader is tested at standstill and in motion. Prior to testing, storage batteries are charged and fuel tank is filled if required.

After starting and warming the engine at standstill, check operation of the clutch, gearbox control mechanisms, functioning of instruments, headlamps and lights, steering system (by turning the wheels to both sides) and hydraulic system of implements (lifting, lowering and sideshifting

the blade). Make sure there is no leakage of oil, fuel or coolant.

Trial run the grader in all gears (after checking operation of the steering system and brakes).

The test results are formalized in the acceptance statement indicating all the defects detected and methods of their elimination.

Running-in. After acceptance of a new or overhauled motor grader, it is necessary to run in the machine, to allow mating parts to become well aligned, transmission and running gear with gradually loading the grader up to the full power limit by the end of the running-in period. Running-in comprises three stages: run-in of the engine at idle stroke for 15-20 min; run-in of the grader in travelling mode for 2-4 h and with different loads for 50-60 h.

Run-in of the engine at idle stroke is started at a minimum crankshaft speed (600-800 rpm) for 5 min with gradually increasing it to a maximum while checking the oil pressure gauge readings. If foreign noise or knocking, leakage of oil or fuel is detected, shut down the engine and rectify the defect.

The grader is run in in the travelling mode during 20-30 min in each gear. In so doing, check operation of the engine transmission, running gear and other components, estimate quality of adjustments and watch the instrument readings.

Then the grader is run in under load in the operating mode with gradually increasing the load to 75% of the engine rated power during first 25 h of operation.

After running in the grader, change oil in all reservoirs, wash cases and filters with diesel fuel and perform maintenance operations according to the instructions.

The completion of running-in should be necessarily formalized by an appropriate statement with relevant entry made in the grader certificate otherwise the manufacturer guarantee will not be valid.

Storage. If a grader is withdrawn from operation for a long time, it should be placed in storage. In case of a short-term storage (up to one month) the clean and filled grader is parked in a place protected against dust and the elements. For prolonged storage the grader should be preserved and placed on a non-flooded ground under a shed.

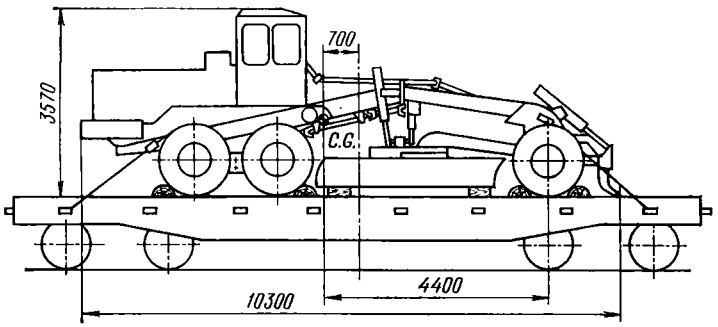


Fig. 15.1. Installation of motor grader on railway flat-car

Prior to preserving, clean the grader of dirt and drain water from the cooling system. Lubricate the machine and fill its oil reservoirs in compliance with the lubrication chart. Arrange front and rear axles on trestles so that the wheels do not touch the support surfaces. Coat all non-painted surfaces of parts and units with dehydrated petroleum jelly heated to 100-120°C. Wipe rubber parts and electric wires dry. Wrap protruding parts of hydraulic cylinder rods with paraffined paper and secure it with twine.

Depreserve the grader at a temperature of not below 15°C. To this end, remove preservation compound and check levels of lubricant and fluids in the grader components and systems.

Shipment. The graders can be shipped from one construction site to another by driving or on railway flat-cars.

When transferring a grader by driving through great distances, the machine should be prepared, its condition checked and fuel and lubricants filled. In case of flat-car shipment, the graders are transported and secured according to the operating instructions (Fig. 15.1).

15.2. Maintenance Practices

List of operations included in different maintenance rounds is given in the grader operating instructions. Engine maintenance is accomplished according to its operating instruc-

tions included in the grader delivery set. The engine operating instructions should be handed over to the operator for study and use in the course of operation.

Prior to performing a scheduled maintenance round, clean the grader of dirt and dust and wash with water.

Given below are maintenance operations for main assemblies and systems of a motor grader.

Engine and its systems. Any maintenance round starts with external inspection for detecting and eliminating leakage of oil, fuel and coolant. During shift maintenance, check oil, fuel and coolant levels and engine idling. Oil pressure at rated crankshaft speed should be 0.3-0.5 MPa, oil temperature in the warmed up engine not above 70°C, water temperature not above 100°C. During scheduled maintenance rounds, check fluid levels in system reservoirs, wash oil, fuel and air filters, lubricate points indicated in the lubrication chart and table. Adjust the valve gear, fuel pumps, nozzles, fan belt tension (belt sag should be 15-20 mm when a force of 70-100 N is applied to it) and lubrication system valves. All these operations should be carried out in volume and terms specified in the engine operating instructions, otherwise the engine manufacturer's guarantee will be invalidated.

Transmission. The clutch should be periodically checked for condition of disk facings, which should not be worn out or oiled. After every 100 h of operation, check the gaps between the release levers and release assembly and adjust clearance of the brake (see Fig. 2.2).

Lubricate the release bearings, articulated joints of axles and levers of the control mechanisms according to the lubrication chart.

With mechanical gearboxes, periodically check oil level in the housing and replace it as required. Drain old oil through the plug immediately after stopping the machine till the oil is still hot. Prior to filling fresh oil, wash the gearbox by pouring 5-6 litres of spindle oil into the housing, starting the engine and running it idle with a gear engaged for 5 to 10 min. This operation is particularly vital for maintenance rounds accomplished after 240 h of operation of a new gearbox when the parts are running in and wear out intensively.

Daily checks include external inspection of the gearbox to detect and eliminate leakage of oil through shaft seals and joint gaskets. Oil pressure in the lubrication system should not be less than 0.05 MPa. Impermissible drop of pressure may stem from clogging of the safety valve, failure of the pump, and leaks in the pipe joints.

The hydromechanical transmission requires very careful maintenance.

The shift maintenance includes checking the oil level in the reservoir and cleaning the hydraulic line filter by turning its lever before the work and checking the oil pressure in the main hydraulic line and torque converter, and the oil temperature and tightness of joints in the course of work.

After 240 h of operation, wash the pan strainer and drain sediment from the hydraulic line filter.

After 480 h, change oil in the hydraulic system, wash all valves and distributors with diesel fuel, blow oil passages and lines with compressed air, check cumulative axial displacements of the input shafts (*22*) (Fig. 2.6) by pressing the clutch housing through the access port. The cumulative displacement should not exceed 0.5 mm. Check the input shaft for easy rotation, condition of gear rims and range slide (to this end, remove the side cover of the transmission).

Maintenance of the grader driving axles consists in well-timed check of oil level in the final drive tandem and in wheel drives and change of it as required. Change oil after 960-1000 h immediately after stopping the machine so that it is still warm.

Systematically clean air passages of breathers clogging of which may impermissibly rise pressure in the axle housing and lead to oil leakage through the glands. Check tightening of bolt joints and absence of oil leakage every day. If oil leakage is detected, tighten the bolt joints or replace the packing glands.

After 960-1000 h of operation, check and if necessary adjust tapered bearings and meshing of bevel gears of the final drive (see Figs. 2.9 and 2.10) as well as the pressure of a limit bolt (*4*) (Fig. 2.9). The final drive bevel gears are selected by the manufacturer in pairs and are run in in the course of operation of the machine, therefore they should be replaced in sets.

After 60 to 100 h of operation, lubricate the needle bearings of the propeller shafts and cavities of its slip joint; after 240-500 h, check tightening of attachment bolts of bearing (*3*) covers and flanges with yoke (*1*) (Fig. 2.12).

Tightening torque of the cover bolts should be 0.1-0.15 J, that of the flange attachment bolts 1-1.2 J. No axial clearance between the propeller drive flanges can be allowed.

After 960-1000 h of operation, check the slip joints. If the clearance is large due to wear-out of the splines, replace the shaft. When replacing separate parts, the propeller shaft should be dynamically balanced after reassembly.

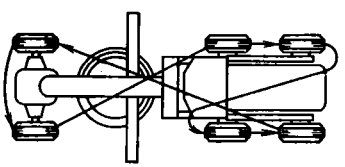


Fig. 15.2. Tyre rotation diagram

Undercarriage and operating equipment. Periodically check and tighten attachment bolts of the front axle and suspension, especially at the initial stage of motor grader operation. After 240-500 h, check and adjust bearings (*13*) of wheel hubs (Fig. 3.2), toe-in and lean (Figs. 3.2, 6.1), eliminate clearances in ball and other joints of reactive rods (*5*) (Fig. 3.3).

To extend tyre life, check air pressure every shift, keep the tyres clean removing sticking materials, never mount them on corroded rims and talc the inner tube while mounting the wheel.

In order to ensure more uniform wear of the tyres, it is good policy to replace the wheels from the front axles to the rear ones and from the right- to the left-hand side. This operation is called tyre rotation (Fig. 15.2).

Shift maintenance includes checking of wheel-to-hub attachment bolts.

Maintenance of operating equipment consists in observation of the recommended clearances of the circle and well-timed adjustment of the turning mechanism (see Sec. 3.2). Clean the surfaces of the circle and gear rim of dirt regularly and lubricate them after 60-100 h of work. Check fasteners of the circle cover plates, supports of draft frame pivot and attachment of scarifier tooth points; lubricate pivot joints.

Braking system. The brakes are the most vital element

of machine control which dictates its safe operation. Particular attention should therefore be paid to them in the course of maintenance rounds.

Inspect the parking brake and clean it of dirt every shift. If the friction linings are worn out so that the distance from their surface to the rivet heads is less than 0.5 mm, replace the linings. After every 100-240 h of work check and adjust clearance between the linings and the drum (see Figs. 4.1 and 4.2).

Periodically inspect the service (wheel) hydraulic brakes, clean them of dust and dirt; after 240 h adjust them (see Fig. 4.3), check tightening of fasteners, shoes, eccentrics and springs of the adjustment device. It is of utmost importance to periodically check friction linings for condition and wear. Ensure against that the rivet head depression is less than 1.5-2 mm. Wash oiled linings with gasoline, rub with a hard brush and dry.

Fill the master cylinder and pipelines of the braking system only with special braking fluid, systematically check tightness of line joints, check fluid level in the cylinder. While adjusting the clearances, set the required free play of the brake pedal (see Fig. 4.4).

In case of wheel disk air brakes, the air system units should be periodically checked. Adjust belt tension of the compressor, clean its valves and seats, check valves for leakage, tighten up fasteners. After every 500 h of work it is recommended to remove the compressor block head to clean parts and check for leakage. While doing this, check plunger sealing rings for condition and replace them if necessary. Lap the leaky valves to the seats. Periodically check the pressure regulator for leakage. Air leakage is detected by the ear when the engine is dead.

In the course of work, periodically check the brake valve for reliable attachment and absence of leakage. Leakage of air through the valve body, valve spring body, pistons and joints cannot be tolerated. To eliminate leaks, disassemble the left-hand cylinder and clean the valve and its seat.

To check the safety valve, pull out the rod (7) protruding from the adjustment screw (Fig. 4.7). If the valve is OK, pulling out the rod will release air to atmosphere.

In the course of shift maintenance, drain condensate from

the air bottle through its cocks. If more than 15-20 cm^3 of oil collects in the bottle daily, the compressor is faulty or its filter clogged. Drain condensate with the air system pressurized.

Hydraulic system. Maintenance of the hydraulic system generally involves periodic inspections and elimination of oil leakage from units and joints and replenishing of the system with oil. After 60-100 h of work, drain sediment from hydraulic system filters and clean the vents in the oil reservoir plug.

After 960-1000 h of work, drain oil from the reservoir and the system, and fill the reservoir with diesel fuel for washing. Alternately engaging each hydraulic cylinder, run the engine at medium speed for 3 to 4 min. Drain diesel fuel and fill the tank with fresh oil. To evacuate air from the system while filling, proceed as follows. Start the engine, set a medium speed of rotation and alternately engage the operating equipment hydraulic cylinders five times each shifting them to the extreme positions, then add oil to the reservoir up to the normal level, run the operating equipment idle for 10-12 min more and then wash the filter.

Use similar procedure when repairing, replacing hydraulic cylinders and eliminating leakage of oil.

After 240-500 h of work, check pressure in the hydraulic system and adjust it by a safety valve built in the hydraulic distributor (see Fig. 5.4).

Steering system. Maintenance includes periodic checks of attachment, clearances and locking of all joints of the rods and arms of the wheel, greasing of joints, checks and addition of oil to the steering gear housing and to the reservoir.

Disassemble the steering gear only whenever necessary. While disassembling the gear, ensure against ingress of moisture, dust and dirt to the parts. Rubber sealing rings can be eventually damaged in assembly, therefore carefully inspect all parts to be mated with the rings and remove all burrs, nicks and other defects before assembly. Prior to assembling, wash the parts of the hydraulic distributor in clean gasoline, kerosene or diesel fuel, dry them and lubricate friction surfaces with a thin layer of working fluid. Wiping the parts after washing is prohibited to exclude getting of rags or other wiping materials into the gear.

Electrical equipment. Maintenance consists in systematic checks of instruments and wiring, settings and readings of gauges against reference meters.

Storage batteries. After 960-1000 h of work, clean the batteries of dirt and coat posts with petroleum jelly. Check the electrolyte level and add it if necessary, clean vents in plugs. Check the electrolyte specific gravity (see Table 7.1) once in three months; if the battery is discharged by 25% in winter and over 50% in summer, forward it for charging.

Check the starter for attachment of wires and solenoid, periodically clean them of dust and dirt. If oil or diesel fuel gets onto the starter, remove it, disassemble the starter and wash it with gasoline.

Periodically test the generator operation by instrument readings, check attachment and drive belt tensioning. After first 960-1000 h of work and then periodically, remove the generator, clean it of dust and dirt, check the brush length which should be at least 8 mm. Grind new brushes to the commutator by emery cloth. Insert a strip of emery cloth between the brushes and the commutator, working side outwards and pull it down the armature direction. Clean the commutator and the brush holders of carbon dust. A polished dark-cherry or violet surface is indicative of normal condition of the commutator.

Seasonal maintenance is an important part of maintenance system. Preparation of the machine for autumn-winter operation includes a special maintenance round for washing the fuel tanks and gearbox housings, rear axle and tandems, filling reservoirs with winter grade oils. Storage batteries are charged with increased-gravity electrolytes and warm jackets of felt or plywood and paper are installed on them. The engine cooling system is filled with antifreeze (if permitted by the operating instructions) after washing the radiator, ducts and block jacket.

Preparation for spring-summer operation also includes a special maintenance round for changing oil and coolant, and filling summer electrolyte (of decreased specific gravity) into storage batteries. Special attention should be paid to the air cleaner because during this period the engine operates under extremely dusty conditions.

15.3. Lubrication and Filling

Lubrication and filling operations take up to 50% of the total volume of work involved in maintenance of a motor grader. Quality of lubrication depends greatly on cleanness of accomplishment of this work. Prior to lubricating or filling, clean the plugs of filler holes and grease fittings as well as the adjacent surface of dirt. When greasing force fresh lubricant through the grease fittings till it protrudes through the joints. When filling reservoirs and housings carefully check oil level since excess oil is as detrimental as its shortage.

Oil servicing trucks are widely used to accelerate lubrication.

The grader operating instructions include lubrication tables and charts indicating points and terms of lubrication and descriptions of lubricants. Presented below as an example are the most typical lubrication points for light (Fig. 15.3) and heavy (Fig. 15.4) motor graders and their lubrication tables (Table 15.1 and 15.2).

Well-timed filling and lubrication of a motor grader provides reliable operation of the machine. Use only those

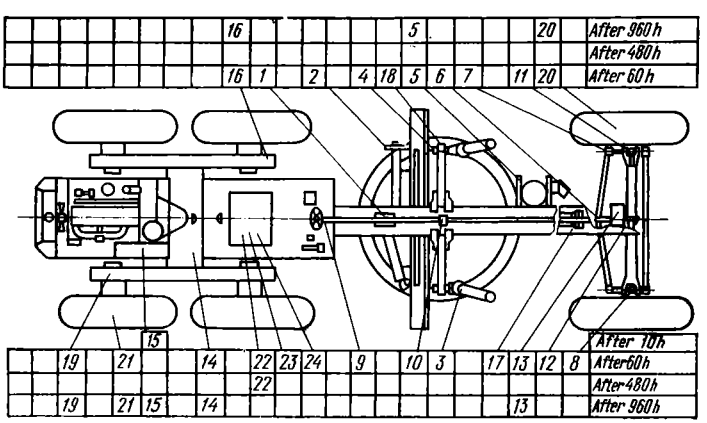


Fig. 15.3. Light grader lubrication chart

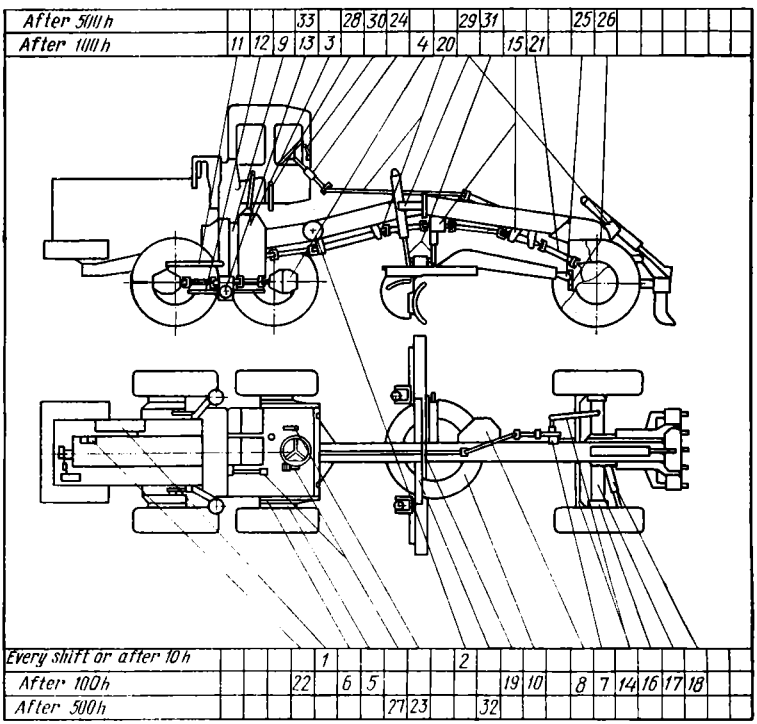


Fig. 15.4. Heavy grader lubrication chart

grades of fuel, working fluids and lubricants which are specified in the instructions. Adhering to the fuelling and storage rules does the engine a good favour. It is recommended to fill the tank with settled fuel to preclude ingress of foreign particles and water into the fuel system of the motor grader. Prior to fuelling, clean the fillers and caps of the tanks of dirt, dust, and remains of fuel.

The operator must save fuel and lubricants by preventing losses in filling and skillfully operating the machine. Prolonged idling, failure of one of the nozzles or maladjustment of fuel equipment may be the cause of fuel overconsumption. Leaks through loose joints of system units and pipelines,

Table 15.1. Light Grader Lubrication Table

Chart ref. No. (Fig. 15.3)	Lubrication point	Number of points	Lubricant at temperature		Lubrication method
			down to −40 °C	up to +50 °C	
			Shift or 10-h maintenance		
15	Hydraulic system reservoir	1	ВМГЗ (ТУ 38-101-479-74), МГ-30 (ТУ 38-101-50-79) —	Oil АУ	Check level, add if required
			First maintenance (after 60 h)		
1	Draft frame sideshift cylinder	2	Solid oil C		Clean grease fitting and pump grease gun three-four times
2	Blade sideshift cylinder	2	Same		Same
3, 4	Blade lifting cylinder	6	Same		Same
6	Steering linkage	6	Same		Same
7, 8, 11, 12	Front axle	10	Same		Same
9, 10	Steering column	4	Same		Same
13	Steering gear	1	Oil МТ-16П	Oil МТ-14П	Check oil level by check plug and add if required
14	Rear axle	1	Same		Check oil level by dip stick and add if required
16, 19	Left- and right-hand tandems	2	Same		Check oil level by check plug and add if required
17	Draft frame	1	Solid oil C		Clean grease fitting and pump grease gun three-four times

Table 15.1 (continued)

Chart ref. No. (Fig. 15.3)	Lubrication point	Number of points	Lubricant at temperature		Lubrication method
			down to −40 °C	up to +50 °C	
18	Circle		Same		Clean gear rim and apply lubricant with brush
24	Propeller drive slip yokes	2	Same		Clean grease fitting and pump grease gun three-four times
22	Gearbox	1	Oil MT-16П	Oil MT-14П	Check oil level by dip stick and add oil if required
23	Propeller shaft crosses	4	Grease 158 (TУ 38-101-320-72)		Clean grease fitting and pump grease gun till old grease is seen
			Second maintenance (after 480 h)		
22	Gearbox	1	Oil MT-16П	Oil MT-14П	Change oil
			Third maintenance (after 960 h)		
5	Blade turning gearbox	1	Solid oil C		Remove old grease. Wash housing with diesel oil, and fill with new lubricant
13	Steering gear	1	Oil MT-16П	Oil MT-14П	Drain oil. Wash housing with diesel fuel and fill fresh oil
14	Rear axle	1	Same		Drain old oil and fill fresh one
15	Hydraulic system reservoir	1	BMГ3 or MГ-30		Change working fluid
16, 19	Tandems	2	—	Oil AУ	Drain old oil and fill fresh one
20, 21	Front and rear wheels	6	Oil MT-16П	Oil MT-14П	
			Solid oil C		Wash parts with diesel fuel and change lubricant

Table 15.2. Heavy Grader Lubrication Table

Chart ref. No. (Fig. 15.4)	Lubrication point	Number of points	Lubricant at temperature		Lubrication method
			down to −40°C	up to +50°C	
		Shift or 10-h maintenance			
1	Engine oil reservoir	1	Oil MT-16П	Oil MT-14П	Check level and add oil if required
2	Hydraulic system reservoir	1	ВМГЗ, МГ-30		Same
			—	Spindle oil АУ	Same
		First maintenance (after 100 h)			
3	Transmission	1	Oil MT-16П	Oil MT-14П	Same
4	Final drive housings	3	Same		Same
5	Tandem drive housings	6	Same		Same
6	Brake housings	4	Same		Same
7	Steering gear	1	Same		Same
8	Blade turning gearbox	1	Same		Same
9	Clutch release bearings	1	Grease ЦИАТИМ-203		Pump grease in till old lubricant appears
10	Blade turning gearbox gear and circle rim	1	Same		Clean of dirt and coat with layer of lubricant
11	Reactive rod ball pins	4	Same		Pump grease in till old lubricant appears

Table 15.2 (continued)

Chart ref. No. Fig. 15.4)	Lubrication point	Number of points	Lubricant at temperature		Lubrication method
			down to −40°C	up to +50°C	
12	Rear axle suspension ball joints	4	Same		Same
13	Tandem axle bearings	4	Same		Same
14	Steering rod ball pins	4	Same		Same
15	Front axle drive joint bearings	5	Same		Same
16	Front axle steering knuckle bearings	4	Same		Same
17	Front half axle bearings	2	Grease ЦИАТИМ-203		Pump grease till old lubricant appears
18	Steering hydraulic cylinder ball pins	2	Same		Same
19	Steering propeller shaft bearing	1	Same		Same
20	Propeller drive cross bearings	19	Grease 158 (ТУ 38-101-320-72)		Same
21	Propeller shaft cavities and splines	6	Same		Fill during disassembly
22	Fuel pump and regulator	2	Oil МТ-16П	Oil МТ-14П	Add to drain plug and check hole levels, respectively
	Second maintenance (after 500 h)				
23	Clutch drive and interlock lever axles	10	Grease ЦИАТИМ-203		Fill grease by grease gun
24	Steering column bearings	2	Same		Same

Table 15.2 (continued)

Chart ref. No. (Fig. 15.4)	Lubrication point	Number of points	Lubricant at temperature		Lubrication method
			down to −40 °C	up to +50 °C	
25	Draft frame pivot	1	Grease ЦИАТИМ-203		Fill grease by grease gun
26	Front axle suspension bearings	2	Same		Same
27	Parking and service brake linkage axles	4	Same		Same
28	Fuel pump regulator axles and lever	5	Same		Same
29	Scarifier and blade hydraulic cylinder trunnions	6	Same		Same
30	Hydraulic distributor lever axles	2	Same		Same
31	Blade hydraulic cylinder bearings	4	Same		Lubricate at disassembly
32	Draft frame suspension mechanism axles	5	Same		Fill grease by grease gun
33	Clutch shaft bearings	1	Same		Fill at disassembly

Note. After first 50 h of operation, every 1000 h and during seasonal maintenance, change oil and working fluid in all reservoirs with necessarily washing housings, filters and magnetic plugs with fuel.

overfilling housings with oil lead to considerable losses of fuel and working fluid.

When changing working fluids and oils, never drain them onto the ground. Used lubricants should be collected and sent for recycling.

15.4. Diagnostic Testing

Diagnostic testing plays an important role in the general volume of maintenance work. It is aimed at determining technical condition of mechanisms and components of the machine to the required accuracy. Diagnostic testing provides for deciding on the need for adjustment or routine repair of separate units and entire grader without disassembly.

In the course of machine operation its initial parameters undergo certain changes, e.g. its power decreases, mating pair clearances increase and so on. Therefore, the machine condition can be estimated by the combination of such changes which are manifested in a particular way and represent the diagnostic test parameters.

The diagnostic test parameters can be grouped according to common features. Thus, vibration, noise and knocking can be used for estimating the condition of the engine, gearbox or driving axle. By comparing fluid pressure and flow rate with the specified values, one can determine the condition of the hydraulic drive, engine systems, etc. Excessive heating of some components may be indicative of increased friction losses. Increased play or control force required also symptomize the machine state.

To estimate the machine condition by reference to the afore-mentioned parameters, use is made of diagnostic test equipment. Mechanical devices while measuring dimensions of parts and forces estimate the degree of wear, clearances in gears, bearings and brakes, threaded joint tightening torques, etc. Acoustic instruments measure noise level for determining variations of clearances, wear and troubles of the engine, closed gears and bearings.

The diagnostic test equipment also includes electrical, and ultrasonic units.

The diagnostic testing of motor graders is included in all types of maintenance and repair operations. A truck-mounted

mobile test set can be used for in-field diagnostic testing. Such a test set includes an electric power and a compressed air source, instruments and devices that allow checking of up to 60 diagnostic test parameters.

Besides, the mechanized equipment bases are equipped with diagnostic test stations.

The purpose of diagnostic testing is to estimate the general technical condition of the engine. Prolonged starting indicates troubles in the starter, fuel equipment, and valve gear, while smoky exhaust is a symptom of abnormal combustion. The crankshaft maximum idle and rated power speeds, engine power, per-hour and specific consumption of fuel can also be checked.

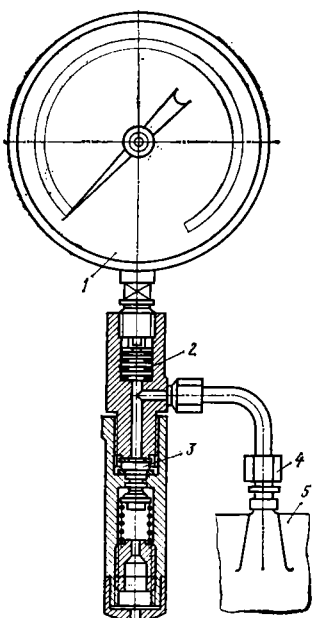


Fig. 15.5. Pressure gauge

1—pressure gauge; *2*—damper; *3*—safety valve; *4*—nut; *5*—fuel pump

When testing the engine mechanisms and systems, subject to checks are oil pressure in the hydraulic line, oil consumption, amount of blow-up gases, leakage of valves, inlet valve opening instant, condition of nozzles and plunger pairs, fuel injection time, condition of oil filters, and fan belt tensioning. Thus, the condition of fuel pump plunger pairs is determined by the pressure at starting which is measured with the use of a pressure gauge (Fig. 15.5). The gauge handle accommodates a damper (*2*) for smoothing fuel pulsations and a safety valve (*3*) set to 30 MPa.

To connect the pressure gauge, turn a union nut (*4*) on the connection of the pump section (*5*) to be checked. Turn on fuel supply and crank the engine to increase the pressure to 25-30 MPa. If the pressure does not reach such a value, replace the pairs.

Fan belt tensioning can be checked by a simple dynamo-

metric device (Fig. 15.6). When a force of 30-70 N is applied to the centre of the belt, the sag should be 10-25 mm. To this end, apply a strip (*1*) of the device to the belt and while pushing a body (*3*) by hand at the afore-said force, read the sag against a graduation on a rod (*2*).

Diagnostic testing of the transmission includes checks of clutch condition and adjustment, cumulative clearance in operation gears and condition of bearings and gears.

Subject to check in motor grader brakes and steering system are quality of brake shoes and shoe clearances, brake pedal travel, steering wheel play, operate pressure of the power steering system, steering force. The steering wheel play can be checked by a protractor (*1*) mounted on the steering column (Fig. 15.7).

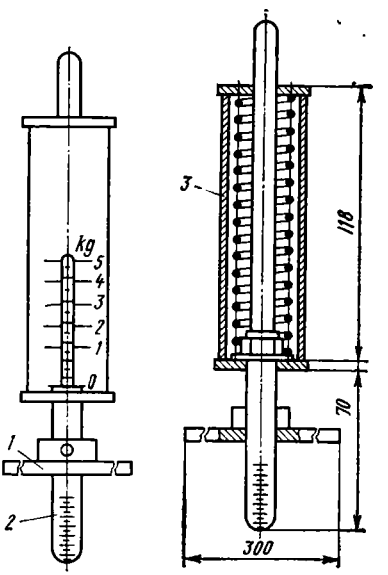


Fig. 15.6. Dynamometric device
1—strip; *2*—rod; *3*—body

The motor grader running gear is checked for condition of tyres (by external inspection and using a pressure gauge) and for toe-in. Toe-in is checked by a telescoping rule with a scale which allows measurements of sizes *C* and *D* (see Fig. 3.2).

Diagnostic testing of grader hydraulic system consists in determining the condition of filters, actuating cylinders, calculating the volume delivery rate of pumps, and safety valve operate pressure. Pump delivery rate is determined by means of instruments one of which, a vane-type transducer, is shown in Fig. 15.8. Fluid flow passing through the transducer rotates a vane (*4*) mounted on a bearing at a speed proportional to the fluid velocity. In each pass of the vane blades, an induction transducer (*5*) induces e.m.f. pulses

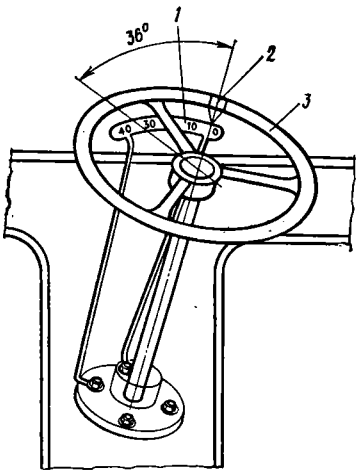


Fig. 15.7. Checking steering wheel free play

1—protractor; *2*—pointer; *3*—steering wheel

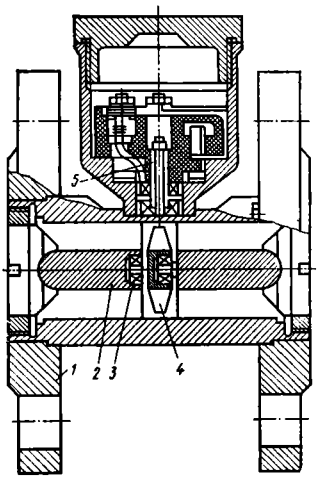


Fig. 15.8. Vane-type transducer assembly

1—body; *2*—fairing; *3*—bearing; *4*—vane; *5*—transducer

therein which are supplied to an amplifier and then to an indicator.

Implementing diagnostic testing methods in the motor grader maintenance schedule provides for fully using the TBO period, decreasing the number of adjustments, shortening dead time because of troubles, and cutting repair expenses.

Chapter 16

MOTOR GRADER ROUTINE REPAIR

16.1. General

Motor grader routine repairs are carried out according to the schedule and are intended at ensuring normal operation between scheduled routine or major repairs.

Routine repair comprises the following stages: preparation of a motor grader for repair and disassembly operations, routine repair of components, assembly of the grader, adjustments and post-repair tests of the machine.

Clean the motor grader of dirt with scrapers and brushes, wash with a jet of water from water mains or a high-pressure pump. Compile a list of defects on the basis of external inspection and troubles encountered in operation. The operator and mechanic should take part in compiling the list.

Position the grader on trestles arranged in the front and rear portions of the frame, drain oil from all housings and reservoirs, fill diesel fuel in its stead and run the engine idle for 5-10 min. Drain diesel fuel from the gearboxes, coolant and oil from the hydraulic system and fuel from tanks.

In case of a heavy grader, remove the cab, cowlings, transmission assembly and driving axles. With a light and medium grader, the tandem is withdrawn from under the frame and the gearbox is removed without dismantling the cab by means of a rope or chain passed through the opening in the floor. Arrange the removed components on supports and disassemble them for repair.

The engine may be repaired with or without removing it from the grader. Replacement of small-end and main bearings, gaskets between the cylinder block and head, lapping and adjustment of valves, as well as the installation of new piston rings, pistons and liners can be accomplished without removing the engine.

The gearbox is partially disassembled by removing the gearshift mechanism, housing side covers and intermediate gear with a clutch (in heavy graders). Then the parts are inspected externally to determine the need for replacement or repair. When inspecting, pay attention to wear of the bearings, gears, forks and levers of the gearshift mechanism and condition of splined and key joints.

The heavy grader tandem and driving axles are disassembled into components (tandem drive housing, final drives, and tandem drives) which in turn are stripped for inspection and repair or replacement of separate parts.

The need for replacement or repair is determined by reference to the list of impermissible defects some of which are given in Table 16.1.

Table 16.1. Impermissible Defects of Some Parts and Assemblies of Motor Graders

Part or assembly	Impermissible defects
Gears and gear couplings	Broken teeth. Cracks. Excessive thinning of teeth. Mutilated, broken or excessively worn splines or key grooves in hubs
Shafts and axles	Any cracks. Worn-out locating surfaces for bearings. Pronounced bending and twisting. Mutilated, broken and worn-out splines or key grooves
Bearings	Impermissible radial and axial clearances. Chipped races, rings, balls or rollers. Damaged cages. Temper colors on races, balls and rollers
Shift forks and levers	Excessive wear of jaws, locating surfaces, deformation
Housings	Cracks extending to joint and locating surfaces. Worn-out locating holes
Friction clutch disks	Warpage of disks and wear of splines
Brake drums and pulleys	Cracks and chippings. Scores and wear on working surfaces
Brake linings	Wear to rivet heads. Cracks and chipping near rivets
Rubber collars, dirt strippers	Cracks and ruptures. Wear on sealing diameter
Non-metal gaskets and seals	Replaced in disassembly
Cab, tanks, cowling, hoods	Excessive deformation. Through corrosion of walls
Main and draft, frames, blade	Through cracks in vital load-bearing areas. Excessive deformation

It is recommended to replace seals of the wheel brake cylinders, master cylinder, and brake and steering hydraulic boosters. All other defects should also be eliminated.

The repaired or new engine, gearbox, driving axles, blade turning mechanism, hydraulic cylinders, brake and steering power units should be run-in under no load and specified load conditions on test beds or on graders. After assembly of the grader, wash the hydraulic system and perform a maintenance round including all necessary adjustments. Then test the grader idle, in travelling and on load. To test the grader idle, jack the machine onto trestles, start the

engine and run the transmission 5 min in each gear successively.

While doing so, check operation of steering, the gearshift mechanism, operating equipment hydraulics, and electrical equipment. During travelling test on an asphalt road, run the grader at least 10 min in each gear and perform several abrupt braking cycles.

The load test consists in operating the motor grader under actual working conditions for at least 2 h. After the tests and elimination of defects, the motor grader is painted.

16.2. Typical Disassembly-Assembly Operations and Measurements

The most typical disassembly operations are unscrewing of fasteners and removal of broken parts, withdrawal of anti-

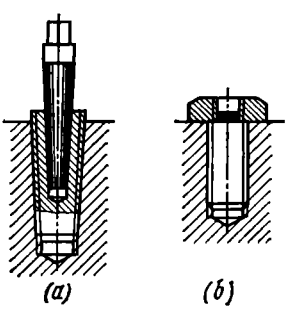


Fig. 16.1. Removing broken studs

(*a*) by serrated rod; (*b*) by welded nut

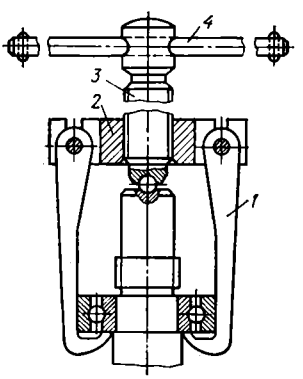


Fig. 16.2. Puller

1—lugs; *2*—body; *3*—screw; *4*—handle bar

friction bearings from shafts and seats, and dismantling of gears from shafts.

The wrenches for nuts and bolts should be of the exact size. Box or socket wrenches are most convenient since they surround all six faces of the nut or bolt head. In case of a hard joint, moisten them with kerosene.

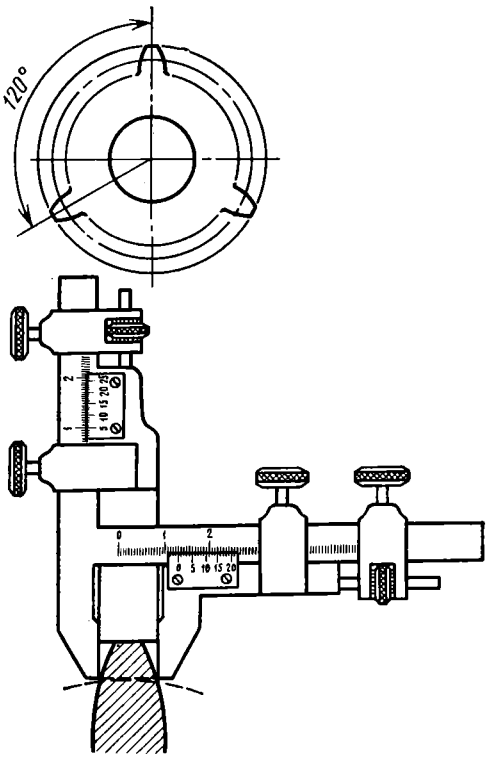


Fig. 16.3. Measuring gear tooth with vernier gauge

Never extend the wrench by improvised handle bars or knock at their stems with a hammer when detaching fasteners.

To remove a broken portion of a bolt or stud from a blind threaded hole, drill a hole in it and drive a square or serrated rod (Fig. 16.1*a*) or weld a nut to its end face (Fig. 16.1*b*).

Antifriction bearings and gears are removed from shafts with the aid of a puller (Fig. 16.2). To remove a bearing, thrust lugs (*1*) of the puller against the outer or inner race. Similar pullers can be of help in removing gears and bushings from shafts. If a puller is not available, use soft steel or copper mandrels.

After disassembly, wash all the parts in kerosene (cold

method) or in alkali solution heated to 80-90°C (hot method) to remove dirt and oil.

Dry the degreased and washed parts and hand them over for inspection to estimate their suitability for further use or the need for repair.

Inspect the parts externally for cracks, chipping, dents, deformation. Using micrometers, vernier calipers, dial gauges, tooth gauges, and plug and snap gauges check the parts selected for repair for wear, deformation and deviation from nominal size.

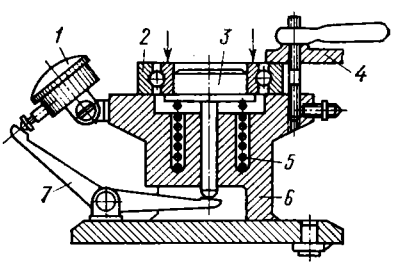


Fig. 16.4. Device for measuring axial clearance of bearings (arrows indicate force application points)

1—dial gauge; *2*—bearing; *3*—slide; *4*—clamp; *5*—spring; *6*—body; *7*—lever

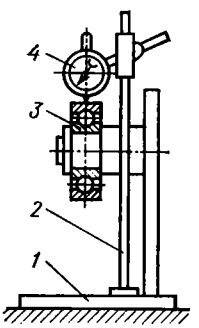


Fig. 16.5. Fixture for measuring radial clearance of bearings

1—support; *2*—upright; *3*—bearing; *4*—dial gauge

Let us consider the most typical grader parts such as gears, ball bearings and splined shafts to illustrate checkout operations.

Wear of gear teeth is determined by a vernier gear-tooth gauge (Fig. 16.3), tangential and optical tooth gauges, and templates. Spur gear tooth wear is estimated by the thickness in two sections. Three teeth spaced through 120° are subjected to measurements.

Ball bearings are inspected for cracks on races, damaged cages and chipped balls.

Axial clearance in bearings is checked by a device (Fig. 16.4) used as follows. Pushing the bearing inner race

with hand leads to up and down displacement of a slide (*3*) linked by a lever (*7*) with a dial gauge (*1*) indicating the value of the clearance. Radial clearance is checked also by a dial gauge mounted on a simple fixture (Fig. 16.5).

Typical defects of shafts of the gearboxes, driving axles and drives include bending, wear-out of bearing locating surfaces and splines.

Bending is determined by a dial gauge while turning the shaft secured in a machine or appliance centres. Locating surfaces are checked by any measurement tools. The purpose of the check is to estimate the degree of part wear and the need for repair. Spline widthwise wear is measured by a vernier caliper or template.

Vital parts are checked for latent defects by magnetic, x-ray and dye-penetrant inspection methods.

Magnetic inspection is based on that magnetic lines of force scatter near latent cracks when a magnetic flux is passed through the part. Magnetic powder or fluid poured over the part surface forms a fault image over its location.

Dye-penetrant inspection consists in applying a penetrant dye onto a degreased surface of the part. After 5 to 10 min the dye is washed off and the part is coated with nitroenamel (or developing dye) which absorbs the dye from the cracks thus exposing them.

Typical assembly operations include assembly of threaded, key and splined joints, gears and bearing units.

When making a threaded joint, see to it that the bolt enters the hole or the nut screws onto the bolt easily without application of excessive force. Tighten bolts and nuts with standard-length wrenches without using extensions. If a part is to be secured at several points, tighten the nuts in a criss-cross manner to avoid deformation.

The threaded end of a bolt or stud should protrude from the nut for one or three turns.

To prevent inadvertent unscrewing, the threaded joints are safetied by locking and spring washers, cotter pins, wire and locking nuts. When a locking nut is installed no other safeties are needed.

Straight and semi-circular key joints (Fig. 16.6) are widely used in motor graders. The keys should readily enter into the slots. A gap of at least 0.1 mm should be provided

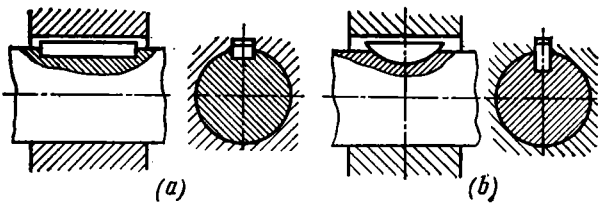


Fig. 16.6. Installing keys
(*a*) straight; (*b*) semi-circular

between the top plane of the key and the part slot bottom. No gaps are allowed in the key joint slots. If the key does not enter into the slot of the part or shaft, fit it to place. When assembling key joints, pay special attention to aligning outer or inner diameters of the parts and side surfaces of splines (Fig. 16.7).

Keys have often to be filed to ensure a quality joint.

Reliable operation of *gears in the gearboxes, drives and driving axles* is considerably dependent on careful assembly. Normal gearing requires optimal clearances between teeth, accurate inter-centre distances and proper mounting of gears on the shaft.

Proper tooth clearances are vital for normal gearing. Small clearances overload the teeth and cause humming. Large clearances result in knocking. Backlash $S_б$ (Fig. 16.8) is checked by a feeler gauge, lead wires and dial gauge fixtures.

To check the backlash with lead wires, they are rolled between the teeth and then their thickness equal to the

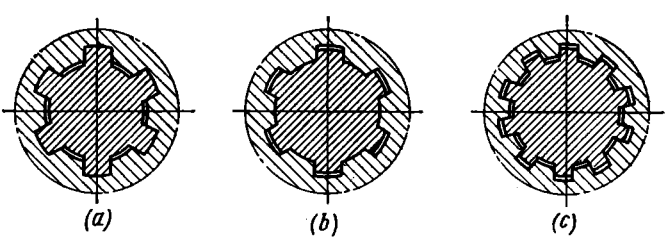


Fig. 16.7. Aligning splines
(*a*) by outer diameter; (*b*) by inner diameter; (*c*) by side surfaces

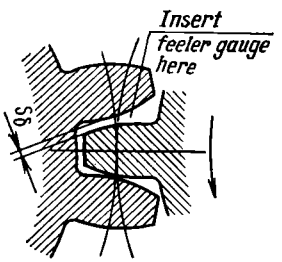


Fig. 16.8. Measuring backlash with feeler gauge

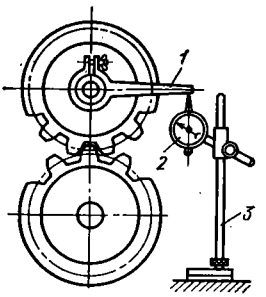


Fig. 16.9. Fixture for measuring backlash

1—lever; *2*—dial gauge; *3*—upright

backlash is measured with a micrometer. The diagram of measuring the backlash is shown in Fig. 16.9.

Checking clearances by the paint-pattern method is illustrated in Fig. 16.10. The motor grader gear backlash should be from 0.16 to 0.25 mm.

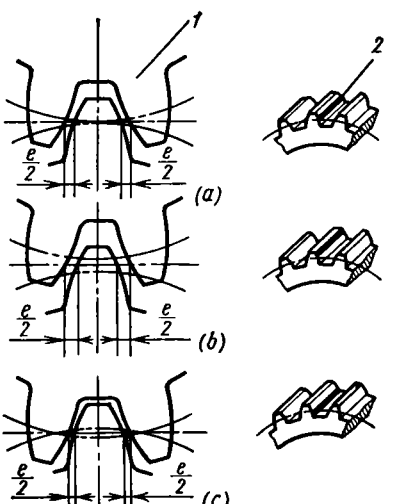


Fig. 16.10. Checking meshing by paint-pattern method

(*a*) proper meshing; (*b*) excessive center distance (incorrect meshing); (*c*) insufficient center distance (incorrect meshing); *1*—meshing diagram; *2*—paint imprint

Relative position of the shafts is also of great importance for proper meshing. The axes of the shafts should lie in the same plane and be parallel to each other. The centre distance should be strictly as specified. This distance changes owing to single-side wear of bearing seats or neglectful machining in repair. A decreased centre distance decreases the clearances which may lead to wedging, while an increased distance increases the clearances which causes excessive wear of the teeth. The centre distance in housings of gearboxes and drives is checked by an inside caliper gauge (Fig. 16.11). Limit deviations of the centre distance are from ± 0.09 to ± 0.24 mm.

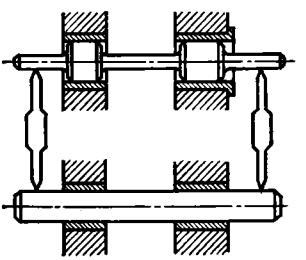


Fig. 16.11. Checking center distance of shafts

Assembly is started with a base part. Thus a base part for a gearbox is its housing. First assemble the shafts with gears and bearings, gearshift mechanism, covers with seals and so on which are small subassemblies of the gearbox. Then all these subassemblies and separate parts are mounted in the housing.

The driving axles are assembled the same way: first assemble the left- and right-hand wheel hubs, final drives and then the driving axle on the whole.

While assembling, lubricate the bearings, adjust meshing and control the rods. Prior to installing rubber seals coat them with oil; metal gaskets should be covered with sealing varnish and cardboard gaskets with solid oil.

16.3. Repair of Principal Assemblies

Let us consider repair of principal assemblies of a motor grader.

The characteristic defects of **clutches** include wear of friction facings of driven disks, burrs and warpage of the driving disk, wear of pressure levers, impaired resilience of springs and damaged housing. Maximum permissible wear of the facing is up to 20% of its original thickness. Crack or chipping are not allowed on plastic and asbestos facings.

The new gaskets are riveted or glued to the steel disk. The countersunk-head rivets are so installed that their heads are sunk for at least 1-1.5 mm. Warped disks are straightened on a straightening plate. Warpage and deformation of the disks should not exceed 0.2 mm. Grooved disks are ground to obtain smooth surface.

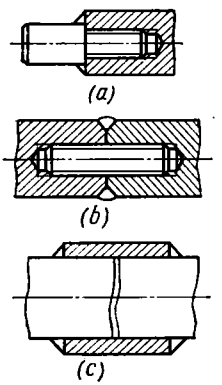


Fig. 16.12. Examples of restoring shafts

(*a*) end journal breakage; (*b*) repair by threaded stud; (*c*) repair by coupling

Worn-out surfaces of pressure levers are restored by hard-alloy build-up.

Cracks in the clutch housing are welded. Stripped or worn-out thread in holes is repaired by installing threaded bushes, rethreading to a repair size, stop welding with subsequent drilling and threading. Worn-out holes for control shaft supports are repaired by pressing bushes into bored holes in the housing.

Main subjects to wear in **gearboxes** are the housing, shafts, gears, geared sleeves, levers, as well as shaft and forks of the gearshift mechanism.

Principal defects of the gearbox housings include wear of bearing seats which are repaired by installing additional or repair-size sleeves. Cracks in the housing walls are welded up or glued.

The shaft may have such defects as deformation, twisting and breakage, worn-out splines and key slots, worn-out and damaged necks and journals, stripped thread.

Deformation is determined by a dial gauge when the shaft is secured in lathe centres. Deformation up to 0.5 mm can be remedied by grinding, if so permitted by the construction. If the shaft bending does not exceed 0.01 of its length, it is straightened in a cold state on a press and is then heat-treated at 400-450°C for 0.5-1 h to relieve internal stresses. In case of a greater bending, the shafts are heated to 600°C at the point of bend and are then straightened on a press. Straightening such shafts is expedient only if

appropriate heat treatment can be subsequently accomplished.

Twisted and broken shafts are replaced. In emergency, the nonvital shafts with broken end journals or middle portion may be repaired with the aid of threaded studs or couplings welded upon installation (Fig. 16.12).

A characteristic defect of splined joint is wear of the spline side surface under the action of great specific loads.

A popular method of repair in this case is to weld up all the splines of the shaft and then to machine them anew.

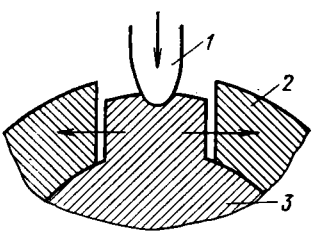


Fig. 16.13. Restoring splines by expansion

1—chisel; *2*—fixture; *3*—splined shaft

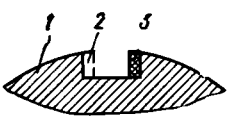


Fig. 16.14. Restoring splines and key slots by welding

1—shaft; *2*—worn side; *3*—built-up side

After welding up the splines, the shaft is turned to the required diameter and is so milled that the new splines are aligned with the old ones.

Slightly worn-out splines can be repaired by calking or expanding by a simple appliance and a blunt chisel as illustrated in Fig. 16.13. The shaft should be annealed beforehand. As a result the spline width may increase by 1-2 mm. After the expansion the notches left by the chisel are welded, the shaft is turned on a lathe, dressed and fitted to the mating part and then heat treated.

When repairing large-diameter splined shafts, the intact side of the spline is built up by welding (Fig. 16.14) and new splines are so milled as to eliminate wear. After such a repair the load will be taken by the non-welded side of the spline.

Minor defects of key joints are eliminated manually by fitter's tools. In case of a greater wear, the key slots are

widened to receive a wider key by building up one side of the slot the way it is done when repairing the splines.

Another common method is to mill a new slot displaced through 90 to 120° from the worn-out one.

Defects in the form of scores, notches and wear within hundredths of millimetre in the locating seats for bearings and other parts are rectified by lapping with pastes or by grinding. Excessive wear of seats is repaired by building up, plating and machining to a repair size.

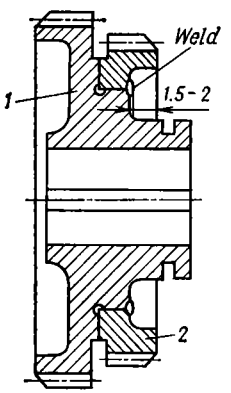


Fig. 16.15. Restoring gear cluster
1—gear cluster; *2*—new rim

Damaged threads are restored by building up and rethreading or (in case of a hole) making new thread of a larger diameter.

Characteristic defects of gears include wear of tooth working surfaces and flanks, chipping or breakage of teeth, damaged splines, key slots and hub locating surfaces.

Restoring working surfaces of teeth is very labour consuming, therefore, modern repair enterprises equipped with appropriate machines prefer to manufacture new gears.

Sometimes it turns out advisable to repair a gear cluster when teeth are worn out on one rim only. The repair is effected by installing an additional part (Fig. 16.15).

The worn-out teeth are turned to form a cylindrical journal to receive the manufactured rim. The new rim (*2*) is heated to 150-200°C in an oil bath and pressed onto the prepared surface of the cluster (*1*). The rim is arc-welded to the cluster. To preclude annealing, welding is accomplished with the cluster immersed in a water bath.

Small chippings at tooth edges are dressed manually with an emery stone to smooth sharp burrs.

Worn-out bevel gears can sometimes be repaired by deepening the tooth space with a cutter to obtain the required profile (see the dotted line in Fig. 16.16) and accordingly cutting the tooth points. If such a repair cannot ensure the required meshing, a shim is placed under the replaceable bevel gear rims.

Minor wear of teeth is eliminated by fitter's technique—dressing burrs and rounding sharp corners; considerable wear is rectified by building up with sormite alloy and then dressing the flanks with a grinding wheel.

Excessively worn-out internal splines in hubs can be restored by installing an additional part with pre-machined splines.

If a hub key slot is worn out, it is advisable to make a new slot displaced through 90 or 120° from the old one.

Wear of locating diameters of a gear hub, say for bearings, is remedied by grinding to a repair size, chrome plating, pressing in an additional sleeve and by other methods.

Gear sleeves with minor wear and scores, sharp edges and chipping are manually grinded on a grinding wheel.

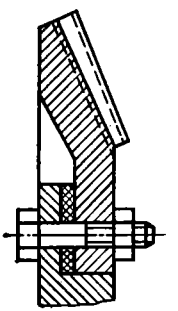


Fig. 16.16. Restoring bevel gear rim

The working surfaces, particularly spherical, of gearbox control levers and guide rails of the gearshift mechanism can be restored by chrome plating or building up. Worn-out working surfaces of the control forks are restored by hard-alloy build-up or welding.

The most frequent defects of the **driving axles, tandem drives and suspensions** of motor graders are encountered in spur and bevel gears, shafts, tandem bronze bushings, and suspension ball pins.

Liable to wear in the bronze bushings serving to support the tandem axles is their inner surface. The bushings with cracks and considerable wear are discarded. Ball pins can be restored by chrome plating. The brake drums suffer from wear of the working surfaces contacting the shoes. The worn-out surfaces of the drum are turned on a lathe in a special fixture.

The front axles suffer from bending of beams, wear of knuckle pin holes and wheel-lean mechanism pins, holes for the axle rocking pivot.

The bent beam is straightened on a press in a cold state. The worn-out holes are bored, reamed and new bushes are pressed in them. In case of minor wear, it is allowed to ream it to a larger diameter and make a new pin.

Characteristic defects of the **running gear** include wear of seats for wheel hub bearings, deformation of rims and disks, wear of disk attachment bolts, wear of tyres and punctures of inner tubes. Worn-out seats in the wheel hub are turned to a larger diameter, then rings are pressed in with an interference fit of 0.05-0.15 mm and then the latter are turned to the required diameter.

Deformed rims and disks are straightened in a cold state on a press. Worn-out holes for the disk attachment bolts are drilled out to a larger diameter. In case of a great wear, the holes are welded around with the use of copper wedges which are withdrawn after welding.

Worn taper holes of the disks are countersunk and taper washers are welded to them.

Worn-out tyres are usually repaired at specialized enterprizes. As a temporary measure it is allowed to repair large cuts and punctures of the tyre by glueing a rubberized cord patch to the inside of the tyre using rubber cement. Inner tube punctures are repaired by cold and hot methods. The cold method consists in glueing patches with non-curing glue. The hot method which is more reliable is vulcanizing with the aid of an electric vulcanizer or vulcanizing pellets.

Electric vulcanizers are used for repair of inner tubes and outer surfaces of tyres. En-route repair of inner tubes can be accomplished with the use of vulcanizing pellets and clamps which allow for patching punctures and bruises up to 40 mm long.

Prolonged operation results in wear of the **hydraulic equipment units** such as pumps, distributors, actuating cylinders, high-pressure hoses and pipes.

The pumps suffer from wear of rubber sealing rings, end faces of bushings and gears. If the cumulative wear of the bushing and gear end faces exceeds 0.2 mm, a set of foil shims is placed under the lower bushings so that the upper ones protrude for 0.1-0.2 mm over the pump housing plane.

Worn-out distributors are replaced. In some cases their

slide valves can be repaired, say by chrome plating followed by lapping to the distributor body.

Hydraulic cylinder defects include ovality, scores and scratches on the mirror and rod surface, damaged rubber seals. Minor defects on the part surfaces are eliminated by grinding and lapping with paste consisting of 75-90% of chromium oxide, 10% of stearine, 5-10% of fat and 2% of kerosene. If wear of the cylinder of up to 120 mm in diameter exceeds 0.07-0.1 mm, the cylinder is replaced in assembly. When repairing the hydraulic cylinders it is necessary to check bending of the rod.

Damaged high-pressure hoses are replaced and leaks in pipelines are stopped by brazing. In case of damage to a pipe threaded nipple or union, they are carefully cut away, the pipe end is cleaned of rust and new nipples are brazed or welded.

Subject to most intensive wear are such **operating equipment units** as the blade cutting edge, scarifier tooth points, ball pivots for attachment of the draft frame to the main frame. Other defects include deformation of the draft frame members and the blade, damage to the cutting edge attachment bolts.

Wear of cutting edges and scarifier tooth points is remedied by hard facing.

The draft frame and the blade are straightened in a cold or hot state depending on the degree of deformation and cross section of the deformed member. The deformed area is heated with gas torches. Various screw clamps, screw jacks and other fixtures are used for straightening.

Damaged bolts are cut away and new ones are installed.

Worn-out ball pivots are restored by chrome plating or steel plating; pivots with excessive wear should be replaced.

The main defects of the grader **frame** are bending and twisting of its structural components, disintegration of welds, cracks and wear of holes for mechanism attachment bolts.

The frame is straightened in a cold or hot state. After straightening it is good policy to reinforce the frame members with cover plates and gussets. It is prohibited to weld cover plates to the frame longitudinal beams by circumferential welds.

Large defects of welds in the part joints are sometimes

chiselled off and welded anew with installing cover plates. Cracks in continuous walls are stop drilled at the ends and welded up.

Chapter 17

SAFETY PRECAUTIONS

Admitted for operating a motor grader may be a person who has finished a trade training school or courses and has been granted an appropriate certificate.

It is prohibited to operate a defective grader. Prior to the work the operator must inspect the machine and eliminate all the detected defects. The grader engine should be dead in the course of inspection.

While en-route the operator should observe all traffic rules and regulations.

Mounting/dismantling of the operating equipment and other heavy operations should be carried out by two workers.

When handling a storage battery, protect the skin, clothes and footgear against electrolyte which contains sulfuric acid dangerous for the skin and fabric.

Antifreezes are strong poisons and should be handled with care. Bear in mind that in winter antifreezes have the ambient temperature and can freeze your hands if getting onto them. Never suck antifreezes with your mouth or use ethylated gasoline for washing.

Prior to starting the engine, set the gearshift lever neutral and apply the parking brake. The engine should be started only by the operator himself.

The grader lights should ensure good visibility of both the route and operating equipment. The horn should be in good repair.

Never adjust, repair or lubricate the grader in motion or with the engine running.

It is prohibited to seat or stand on the frame, axles or mechanism on the moving grader.

Never leave the grader unattended when its engine is running. If the operator has to leave the grader for some

time, he should apply the parking brake and shut down the engine.

Never park the grader at slopes.

Never stay under the grader frame when the blade is lifted.

No unauthorized persons are allowed in the cab of the grader at work. Never remove occasional items from under the blade during operation of the grader.

Check water level in the radiator with the engine idling at low speed. Never open the radiator cap of the overheated engine with ungloved hands. Prior to removing the cap, turn it loose to release steam from the radiator and then remove it fully. While doing so, stand with your back upwind turning your face as far away from the filler as possible.

Prior to removing or installing the wheels, shut down the engine, apply the parking brake, place chocks and jack the required side of the grader.

Never run the grader with the doors unfastened. When travelling, see to it that the additional seat door is closed.

Carry out maintenance and repair operations after the engine stops dead. Use only sound tools specified in the relevant documents. Never extend the wrench arm by lengths of pipes or knock at the wrench with a hammer.

A wide range of power tools is used for repair. Portable tools should be fed from 127/220 V mains and have grounded bodies.

Always wear insulation gloves and boots when using power tools.

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Printed in the Union of Soviet Socialist Republics